ARM WEIGHTLIFTING EXERCISE IN CARDIAC PATIENTS

INTRA-ARTERIAL PRESSURE DURING ARM WEIGHTLIFTING EXERCISE IN CARDIAC PATIENTS

By

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ABSTRACT

This study investigated the circulatory response to double-arm weightlifting exercise and compared the responses during free weight and machine equipment weightlifting in eight patients (mean age = 57.6±10 years) with well-documented coronary artery disease. Subjects performed bench press and overhead press exercises at 40 and 60% of 1 repetition maximum using both the free weights and machine equipment. Intra-arterial pressure was measured in the subclavian artery using a Millar catheter-tip pressure trandsucer. Arterial pressures rose in parallel with both modes of lifting (free weight and machine equipment), while heart rate did not increase substantially. Mean peak systolic (169 to 197 mmHg) and diastolic (95 to 119 mmHg) pressures recorded during the final repetitions of each weightlifting set did not, however, exceed values considered to be acceptable for dynamic exercise. Individual subjects recorded diastolic pressures as high as 150 mmHg during one or more of the weightlifting exercises, and individual mean arterial pressures reached values as high as 181 mmHg during overhead press machine equipment exercise at 60% of 1RM. While these high arterial pressures associated with weightlifting exercise increased myocardial oxygen demand (RPP=9643 to 15290), the increase in diastolic pressure may have augmented oxygen supply (DPTI=3448 to 3926

$mmHg{\bullet}s{\bullet}min^{-1}$). However, because of the proportionately larger increase in RPP compared to DPTI, the ratio of oxygen supply to demand decreased with arm weightlifting exercise (DPTI:RPP=0.3741 to 0.2629). Nevertheless, the estimated myocardial oxygen supply to demand relationship appears to be more favourable during double-arm weightlifting exercise compared to estimated values from previous maximal cycle ergometer testing. These results suggest that double-arm weightlifting exercise at 40 to 60% of 1RM is safe and appropriate for patients with coronary artery disease and can be performed using either free weights or machine weightlifting equipment.

This thesis is dedicated to....

....the cardiac patients whose interest in this thesis study and support of the MacTurtle Cardiac Exercise Rehabilitation Program must have allowed them to withstand the Millar catheter.

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1.0 INTRODUCTION

Although there have been significant declines in cardiovascular disease morbidity and mortality over the past few decades, coronary heart disease remains the leading cause of death in Canada and most of the industrialized countries of the world (Feinleib, 1995; Nault & Wilkins, 1995). While the incidence of heart disease is declining, the prevalence is increasing dramatically with advances in medical knowledge and technology, and the treatment of heart disease has become a major source of health care expenditure worldwide (Avezum, Flather & Yusuf, 1994). The potential of exercise, however, in the primary and secondary prevention of coronary heart disease and in the savings of millions of health care dollars is substantial, and it has been suggested that physical activity could be today's "best buy" in public health (Morris, 1994).

1.1 PATHOPHYSIOLOGY AND ETIOLOGY OF HEART DISEASE

Coronary heart disease is almost always the result of atherosclerosis, a progressive disease characterized by a thickening in the intimal layer of the blood vessel wall due to the accumulation of lipids. The most accepted theory of the development of atherosclerosis is the response-to-injury hypothesis which suggests that plaque formation begins in response to injury to the endothelial lining of the vessel wall. Injury results in the accumulation and proliferation of smooth muscle cells in the intima and the formation of the atherosclerotic plaque

(Ross & Glomset, 1976a, 1976b; Ross, 1986). The majority of lesions in the coronary arteries tend to occur proximally in the three main arteries at their points of bifurcation, and symptoms of ischemia in cardiac patients usually correlate with lesions that result in at least 60-75% occlusion of the lumen of the coronary artery (Brannon, Geyer & Foley, 1988; ACSM, 1988).

Based on the results of the Framingham Heart Study (Kannel, McGee & Gordon, 1976), several risk factors for the development of coronary heart disease have been established. These risk factors include cigarette smoking, hypertension, elevated serum levels of cholesterol, abnormal glucose tolerance (diabetes), family history of early atherosclerosis (onset at less than age 60), sedentary lifestyle, male gender, age, stress and Type A behaviour (Blessey, 1985). Most important to the present study is the strong inverse relationship between physical activity and coronary heart disease (Blair et al., 1993). Furthermore, exercise programs for the primary and secondary prevention of coronary heart disease can lead to significant risk factor reduction. Thus, cardiac exercise rehabilitation may potentially be important in retarding the atherogenic process associated with coronary heart disease.

1.2 HISTORICAL PERSPECTIVES ON EXERCISE REHABILITATION

The importance of physical activity for patients with heart disease was noted over 200 years ago. Heberden, in 1772, published a report referring to a patient with angina pectoris "who set himself the task of sawing wood for half an hour every day and was nearly cured". This initial positive attitude toward physical activity in the treatment of heart disease was, however, forgotten, and following Herrick's clinical description of myocardial infarction in 1912, patients were generally confined to bed rest for 2 months. The fear was that physical activity would result in ventricular aneurysm, heart failure, cardiac rupture and sudden death (Certo, 1985).

In the late 1930's, work by Mallory and colleagues (1939) reinforced the supposed importance of bed rest following an acute myocardial infarction. They described the speed of healing of myocardial infarction as a one to two month process from initial necrosis to the formation of a fibrous scar. It was therefore suggested that to advise less than three weeks bed rest would be unwise, even for patients with the smallest myocardial infarcts.

By the late 1940's, studies had appeared which questioned the traditional prescription of prolonged bed rest and physical inactivity following an acute myocardial infarction (Dock, 1944; Harrison, 1944; Taylor et al., 1949). Levine and Lown (1951) were the first to advocate the chair treatment of acute coronary thrombosis. Patients were kept in a chair for varying and increasing portions of the day beginning no later than the first week following the attack. This method of treatment was shown to have both physiological and psychological benefits, and raised questions as to the appropriateness of prolonged bed rest in the treatment of cardiac patients.

The concept of early ambulation was first characterized by Newman et al. (1952) as 3 to 5 minutes of walking along the bedside twice daily, beginning 4 weeks after myocardial infarction. Brummer and colleagues (1956) soon reported the safety of early ambulation within 14 days of a myocardial infarction. By 1957, Hellerstein, a well-known cardiologist, described an orderly plan for the rehabilitation of the patient with heart disease. His plan suggested that the period of bed rest be as brief as possible, and that exertion in the form of graded exercise be advised. A similar program was developed by Cain, Frasher & Stivelman (1961) to provide a sequence of increasing activity levels for safe return to self-care after myocardial infarction. These reports did much to increase awareness of the safety and potential benefits of early mobilization in the treatment of heart disease.

The late 1960's and early 1970's brought a flurry of research devoted to early mobilization and shortening of the length of hospital stay following an acute myocardial infarction (Abraham et al., 1975; Bloch et al., 1974; Boyle & Lorimer, 1973; Harpur et al., 1971; Hutter et al., 1973; Lamers et al., 1973). With this research came what we now define as phase I (inpatient), phase II (outpatient) and phase III/IV (community based) cardiac rehabilitation. Even as early as the 1960's, studies investigating the benefits of physical training in the management of coronary artery disease began to appear. Cardiac exercise rehabilitation has now become an accepted form of treatment for patients with coronary artery disease (O'Connor et al., 1989).

The traditional approach to cardiac exercise rehabilitation has been to involve large muscle groups in aerobic activities such as walking and stationary cycling (McKelvie & McCartney, 1990). The training effects and benefits of this type of exercise in cardiac patients are now well documented (Bjernulf, Boberg & Froberg, 1974; Clausen, Larsen & Trap-Jensen, 1969; Detry et al., 1971; Frick & Katila, 1968; Hagberg, 1991; Kasch & Boyer, 1969; Oldridge et al., 1989; Paterson et al., 1979; Redwood, Rosing & Epstein, 1972; Varnauskas et al., 1966). Training effects include an increase in maximal oxygen uptake, improvements in resting and exercise heart rate and arterial pressure, increased myocardial oxygen supply, decreased myocardial oxygen demand and a decrease in the angina threshold or increase in time to onset of angina. Recent meta-analyses have also demonstrated a reduction in mortality (O'Connor et al., 1989; Oldridge et al., 1988). Furthermore, exercise training has been shown to have a beneficial effect on other coronary heart disease risk factors and in reducing patient anxiety and depression (Bernadet, 1995; Ewart, 1989; Goldberg, 1989; Haskell, 1994).

Although aerobic exercise has been shown to be a safe and effective form of exercise in the primary and secondary prevention of heart disease, it does not address an important component of rehabilitation, namely muscle strength. This despite that fact that many activities of daily living such as lifting, carrying and stair climbing, require significant amounts of muscle strength. Recent studies have indicated that a decrease in muscle strength may be common among cardiac patients (McCartney et al., 1989; Oldridge et al., 1989). Weightlifting training has been shown to be an effective form of exercise in increasing muscular strength (Gettman et al., 1978; Harris & Holly, 1987; Stewart, Mason & Kelemen, 1988; Stewart, 1989). However, it has not traditionally been used in cardiac exercise rehabilitation.

1.3 CARDIOVASCULAR RESPONSE TO STATIC (ISOMETRIC) EXERCISE

Weightlifting has traditionally been avoided in cardiac patients due to fears of an inappropriate rise in arterial pressure. These fears have probably been based on the acute cardiovascular response to static (isometric handgrip) exercise. Substantial increases in systolic and diastolic pressure occur, and mean arterial pressure commonly increases to 140 mmHg during sustained isometric handgrip exercise (DeBusk et al., 1978; Hanson & Nagle, 1987; Lind, 1970). Smaller increases in cardiac output have been demonstrated in cardiac patients, with no change or a decrease in stroke volume and a small increase in peripheral resistance (Hanson & Nagle, 1987; Helfant, DeVilla & Meister, 1971). Furthermore, significant increases in left ventricular end diastolic pressure occur, suggesting an increased pressure load on the heart (Hanson & Nagle, 1987; Helfant, DeVilla & Meister, 1971; Longhurst & Stebbins, 1992). These changes associated with isometric exercise have been viewed as potentially dangerous in cardiac patients (Lind, 1970).

In comparing the cardiovascular responses to static and dynamic exercise in patients with coronary artery disease, however, several studies have demonstrated that these fears may not be warranted (DeBusk et al., 1978; Ferguson et al., 1981; Kerber, Miller & Najjar, 1975). Kerber, Miller & Najjar (1975) evaluated the effects of isometric (handgrip) and combined isometric-dynamic (treadmill plus briefcase) exercise compared to a submaximal treadmill stress test. Isometric exercise was much less likely to produce myocardial ischemia than dynamic exercise. It was concluded that higher arterial diastolic (coronary perfusion) pressure may retard the development of myocardial ischemia during isometric or combined isometric-dynamic exercise in cardiac patients. DeBusk et al. (1978) compared the cardiovascular responses to dynamic exercise (arm and leg ergometry to exhaustion) and static exercise (handgrip contraction at 25 and 50% of maximal voluntary contraction) seven weeks after myocardial infarction. It was found that ischemic ST segment depression and ventricular arrhythmias were more frequent with dynamic exercise. In a third study, Ferguson et al. (1981) compared coronary blood flow during sustained isometric handgrip of 30, 50 and 70% of maximal voluntary contraction to that during symptom-limited bicycle ergometer leg exercise. They concluded that the lower incidence of ischemia in isometric exercise compared with dynamic exercise was due to a lower myocardial oxygen demand and possibly a greater subendocardial perfusion.

1.4 CARDIOVASCULAR RESPONSE TO STATIC-DYNAMIC EXERCISE

Most activities of daily living are a combination of static and dynamic exercise. Several studies have investigated the cardiovascular response to this type of exercise in patients with coronary artery disease (Bertagnoli, Hanson & Ward, 1990; DeBusk et al., 1979; Kerber, Miller & Najjar, 1975; Sheldahl et al., 1985; Wilke et al., 1985, 1989).

Sheldahl et al. (1985) had patients lift 30-50 pound boxes for 30 minutes (four 6-minute stages with 2 minute rest periods between each stage) which averaged 85% of each patient's maximum oxygen consumption. While significant fluctuations in systolic and diastolic pressures were observed with lifting and releasing of the weight, patients did not demonstrate an increased risk with repetitive static-dynamic lifting. In similar weight-carrying studies (Wilke et al., 1985, 1989), patients did not demonstrate ischemic responses and the incidence of arrhythmias was rare. Furthermore, an attenuation of exercise-induced ST segment depression has also been demonstrated during static-dynamic exercise (treadmill walking 1.5 to 2.0 mph carrying 15 to 25 kg) (Bertagnoli, Hanson & Ward, 1990). Thus, it appears that combined static and dynamic exercise is well tolerated in patients with coronary artery disease.

1.5 SAFETY OF WEIGHTLIFTING IN CARDIAC PATIENTS

Weightlifting is a form of static-dynamic exercise which has consistently been shown to be safe and acceptable in patients with coronary artery disease. Following is a summary of the acute cardiovascular response to weightlifting, and the effects and benefits of weightlifting training in cardiac exercise rehabilitation.

1.5.1 Acute Cardiovascular Response to Weightlifting

For weightlifting to be an accepted form of exercise in cardiac patients, cardiovascular responses should be no greater than those considered to be acceptable in dynamic exercise. The cardiovascular response during weightlifting compared to dynamic exercise in patients with coronary artery disease has been examined by a number of investigators (Butler, Beierwaltes & Rogers, 1987; Faigenbaum et al., 1990; Featherstone, Holly & Amsterdam, 1987, 1993; Haslam et al., 1988; Vander et al., 1986; Wiecek, McCartney & McKelvie, 1990).

In a study by Vander et al. (1986), the acute cardiovascular and electrocardiographic responses during Nautilus resistance exercise were compared to those found during symptom-limited graded treadmill exercise testing. Nautilus stations included 1 abdominal, 1 lower back, 5 lower extremity and 6 upper extremity exercises performed at 40-60% of maximal voluntary contraction. In contrast to the treadmill exercise testing, no significant arrhythmias, abnormal hemodynamics, ST segment depression or symptoms occurred during Nautilus exercise. Therefore, it was suggested that Nautilus exercise using light to moderate loads is relatively safe for cardiac patients.

Butler, Beierwaltes & Rogers (1987) used echocardiography to evaluate left ventricular wall motion following a session of upper body circuit weight training and traditional aerobic treadmill exercise. While a worsening of wall motion, indicative of the development of exercise-induced ischemia, occurred in 5 of 61 left ventricular segments with aerobic exercise, only 1 segment showed a worsening of wall motion with circuit weight training. It was concluded that circuit weight training compared favourably with traditional aerobic exercise and appears to be a safe form of training in patients with heart disease.

Faigenbaum et al. (1990) investigated the physiologic and symptomatic responses during moderate to heavy resistance exercise in cardiac patients. Subjects performed 2 sets of seven repetitions at 75% of maximum voluntary contraction on each of seven upper body resistance exercises. Indirect measures of systolic and diastolic pressures (measured immediately following exercise), heart rate and rate-pressure product were all within normal limits and no patient complained of angina or developed ischemic electrocardiographic changes. These results suggest that aerobically trained cardiac patients may perform moderate to heavy resistance exercises without experiencing complications.

Recent studies by Featherstone, Holly & Amsterdam (1987, 1993) assessed the safety of, and the physiological responses to, weightlifting at 40, 60 80 and 100% of maximal voluntary contraction compared to maximal treadmill exercise. Weightlifting included double-leg quadricep extension, and single-arm overhead press, bench press and biceps curl to allow for indirect blood pressure measurement at peak exercise in the nondominant arm. Peak systolic blood pressures were found to be similar for weightlifting and aerobic exercise, whereas the peak diastolic pressures were significantly higher during weightlifting. The peak heart rate response was lower during weightlifting with an accompanying decrease in the peak rate-pressure product (RPP). The lower peak RPP during lifting suggests that myocardial oxygen demand was less during weightlifting. Furthermore, as coronary blood flow occurs mainly during diastole, the slower heart rate (longer diastolic time period) and higher diastolic pressure (increased coronary perfusion pressure) associated with weightlifting (McKelvie & McCartney, 1990) would improve myocardial oxygen supply, as was indicated by a higher diastolic pressure time index. Thus, the estimated myocardial oxygen supply-to-demand ratio appears to be more favourable during weightlifting.

It should be cautioned that the application of the DPTI may not be appropriate for an atherosclerotic coronary artery because arterial pressure falls across a coronary obstruction (Epstein, Cannon & Talbot, 1985). This pressure drop varies directly with the length of the stenosis, and more importantly, inversely with the fourth power of the vessel radius (Epstein, Cannon & Talbot, 1985). In other words, the larger the obstruction and smaller the radius, the greater the resultant pressure drop. Consequently, the myocardial perfusion pressure is determined by the gradient between the diastolic coronary pressure distal to the obstruction and the left ventricular end-diastolic pressure (Epstein, Cannon & Talbot, 1985). Therefore, the DPTI calculated from the pressure gradient between the aorta and left ventricle would overestimate the coronary blood supply to the myocardium (Braunwald & Sobel, 1992).

In a study by Haslam et al. (1988), blood pressure was measured directly using an intra-arterial catheter placed in the brachial artery. Subjects performed repetitions of single-arm curls, and single-leg and double-leg presses at 20, 40, 60 and 80% of maximal voluntary contraction. The magnitude of the pressor response varied according to the amount of weight lifted, with peak systolic and diastolic pressures occurring at 80% of maximum. These increases in pressure were substantially greater than those found in studies where blood pressure was measured indirectly after exercise using a sphygmomanometer (Faigenbaum et al., 1990; Featherstone, Holly & Amsterdam, 1987, 1993). Only the double-leg exercise at 60% and single-leg and double-leg exercise at 80% elicited a maximal rate-pressure product that exceeded the value at 85% of maximum power output during cycle ergometer testing. This comparison between weightlifting and dynamic exercise would probably be more favourable, however, had arterial pressure been measured directly during cycle ergometer testing, as systolic blood pressure (and rate-pressure product) is typically underestimated by 15% using indirect blood pressure measurement methods (Wiecek, McCartney & McKelvie, 1990). It was concluded that weightlifting exercises that used relatively few repetitions (10-15) and a resistance of less than 80% of maximum voluntary contraction resulted in clinically acceptable arterial pressure responses.

A comparison of direct and indirect measures of arterial pressure during weightlifting was undertaken by Wiecek, McCartney & McKelvie (1990) in patients with coronary artery disease. Simultaneous direct (brachial artery catheter) and indirect (auscultation) measures of blood pressure were taken at rest, immediately before, during and after weightlifting exercise. Subjects performed 15 repetitions of single-arm curl, single-arm military (overhead) press and single-leg and double-leg press exercises at 40 and 60% of maximum voluntary contraction. Indirect measures of systolic blood pressure underestimated direct systolic pressures by 13 (at rest) to 34% (immediately after arm exercise), while diastolic pressures were similar using either method. The highest intra-arterial pressures were recorded during the final repetitions of the set, and immediately after the last repetition, both systolic and diastolic pressures decreased within 1 to 2 seconds to near resting values. Thus, it does not appear to be possible to draw conclusions about the pressor response during lifting from measurements made immediately following weightlifting exercise.

1.5.2 Benefits of Weightlifting Training in Cardiac Rehabilitation

Most studies on the effects of weightlifting training have had cardiac patients perform multiple sets of 12 to 15 repetitions, with light to moderate loads of 30 to 50% of 1 repetition maximum. This approach to weightlifting which combines reduced intensities with a greater number of repetitions, results in modest gains in muscle strength as well as increased muscular endurance. Following is a summary of the effects and benefits of weightlifting training in cardiac rehabilitation.

1.5.2.1 Effects of Weightlifting Training on Muscle Strength

The first study was published by Kelemen and colleagues (1986) investigating the safety and efficacy of 10 weeks of circuit weight training in patients with documented coronary artery disease. All patients had participated in a supervised cardiac rehabilitation program for a minimum of 3 months before the study (mean number of months was 30-40). Subjects were randomized to control and experimental groups, each group continuing with their regular walk/jog exercise routine, while the experimental group substituted circuit weight training for a volleyball program. Circuit weight training consisted of 2 sets of 10-15 repetitions of 10 arm, leg and abdominal exercises performed at 40% of 1 repetition maximum (1RM). Following the 10-

week training program, the 1RM increased significantly in all but one exercise in the weight trained group (average 24% increase in strength) compared to an increase in only 1 leg exercise in the control group. Furthermore, a significant improvement in treadmill time (symptom-limited standard Bruce protocol exercise test) in the circuit weight trained group compared with the control group was also observed, which was a surprising finding as both groups had continued their aerobic exercise training program. Thus, circuit weight training, when added to an aerobic exercise program, appears to be safe and to result in significant increases in aerobic endurance and musculoskeletal strength compared with traditional exercise.

In a similar 10-week weight training study, McCartney et al. (1991) compared the effects of combined weightlifting and aerobic training (n=10) with the effects of aerobic training alone (n=8) on strength and maximal power output in 18 men with coronary artery disease. The weightlifting training consisted of 4 single-limb exercises performed in turn by both limbs. Initially subjects performed 2 sets of 10 (arms) to 15 (legs) repetitions at 40 to 50% of 1RM, which was gradually increased to 3 sets at approximately 80% of 1RM by the end of the study. After 10 weeks, the average increase in 1RM in the combined training group for all exercises was 29% compared to an average increase of 8% in the control group. More importantly, in the combined training group, the pre-training 1RM could now be lifted an average of 14 times. This suggests that many strength-related activities of daily living that would require almost maximal effort before training may be reduced to a submaximal level even after only a short period of weightlifting training. Combined training also resulted in a 15% increase in maximal power output during cycle ergometer testing, which was in agreement with the results of Kelemen et al. (1986). It was suggested that this improvement may be related to the attenuation of perceived exertion (diminished effort) arising from stronger leg muscles, which could result in improved function in many strenuous activities of daily living and an enhanced quality of life.

Sparling et al. (1990) examined the effect of a 6 month circuit weight training program on blood pressure and strength. Circuit training consisted of 12-20 repetitions at 30 to 40% of 1RM on 12 Nautilus exercises performed three times per week along with the patient's aerobic exercise program. While no significant changes in blood pressure occurred with training, significant increases in strength were observed with a mean increment of 8.2 kg or 22% for all 12 exercises. It was concluded that a carefully supervised, long-term program of low-resistance strength training appears to be safe and beneficial in terms of strength gain in cardiac patients.

A three-year follow-up study of patients involved in circuit weight training was conducted by Stewart, Mason & Kelemen (1988). Muscular strength in 17 circuit weight trained men who had attended greater than 50% of available sessions over a 3 year period was compared to 8 patients who had participated in a cardiac aerobic exercise program. Only the circuit weight trained patients improved arm and leg strength by 13 and 40%, respectively.

The safety of a much higher intensity resistance training program in aerobically trained, male cardiac patients was investigated by Crozier Ghilarducci, Holly & Amsterdam (1989). The 10 week program consisted of 8-12 repetitions of 6 resistance exercises performed 3 days per week at 80% of maximal voluntary contraction. Strength gains of 12-53% were reported which, on average, were greater than those reported by others (Kelemen et al., 1986; Stewart, Mason & Keleman, 1988; Sparling et al., 1990). This finding was expected with a training intensity of 80% compared to 30 to 50% of maximal voluntary contraction, although it is difficult to draw conclusions from these results as no control group was included in this study.

The weightlifting training studies mentioned thus far have included low risk cardiac patients who had participated in traditional cardiac exercise rehabilitation for at least 3 months prior to the addition of weightlifting training. However, several recent studies have examined the effectiveness and safety of strength training in patients early after myocardial infarction (Daub, Knapik & Black, 1996; Stewart et al., 1994; Squires et al., 1991).

The first report of the safety of weightlifting training in Phase II cardiac rehabilitation was by Squires et al. (1991). They examined the hemodynamic responses to weightlifting in 13 male cardiac patients 7-8 weeks following myocardial infarction or coronary artery bypass graft surgery. Subjects performed 1 set of 10-14 repetitions of 3 weightlifting exercises 3 times per week for an average of 6 sessions (range 2 to 12). No clinical complications or electrocardiographic signs of ischemia or arrhythmia were seen. Furthermore, although 1 repetition maximums were not measured, training loads increased by 70 to 82%. It was concluded that moderate weight training is feasible and safe for cardiac patients as an adjunct to aerobic exercise training during early outpatient rehabilitation.

Stewart and colleagues (1994) conducted a randomized trial of circuit weight training in male cardiac patients enrolled into rehabilitation as soon as 2 weeks after an acute myocardial infarction. All patients participated in traditional exercise rehabilitation for 2 weeks, at which point baseline testing and randomization took place. For the following 10 weeks, control patients (n=7) continued with their usual exercise program while the weight training patients (n=8) cycled for 10 minutes and then performed 2 circuits of 12-15 repetitions of 6 weight exercises at 40% of 1RM. Telemetry ECG showed no sustained arrhythmias or ischemic episodes during training, and there were no adverse events. Weight training patients increased their 1RM strength by 22 and 29% for the arms and legs, respectively, while control patients showed smaller changes in leg strength and no change in arm strength. Weight trained patients also showed a 15.5% increase in maximal oxygen uptake during cycle ergometer testing, whereas no change was observed in the aerobic training control group. Thus, circuit weight training can be safely incorporated into the rehabilitation program early after myocardial infarction, and may result in greater increases in strength and maximal oxygen uptake than those observed with a cycling only program.

In a recent study, Daub, Knapik & Black (1996) examined the safety and effectiveness of strength training at different intensities in patients early after myocardial infarction. Fifty-seven men, 6 to 16 weeks post-infarction, were randomly assigned to a control group or one of three treatment groups. All groups trained aerobically, 3 times per week for 12 weeks. The three treatment groups also performed 6 upper body strength training exercises on each training day of the last 10 weeks. The treatment groups differed in their strength training intensity with group 20 performing 20 repetitions at 20% of 1RM, group 40 performing 10 repetitions at 40% of 1RM and group 60 performing 7 repetitions at 60% of 1RM. In the three treatment groups, 30 of 42 subjects had one or more cardiovascular complications during aerobic exercise as compared to only 1 subject with complications during weightlifting exercise. Maximal strength remained unchanged in the control group, but increased in groups 20, 40 and 60 by 10.5%, 11.9% and 13.5%, respectively. The increases in strength in the treatment groups were all significantly different from the results of the control group, however were not significantly different from each other. The fact that significant gains in strength resulted from weight training at a very low intensity (20% or 1RM) has clinical significance when higher risk patient populations are being considered. Thus, as the majority of cardiac patients return to work within 4 months of their myocardial infarction (Daub, Knapik & Black, 1996), with uncomplicated patients returning as early as 4 weeks post-infarction (Dennis et al., 1988), the use of weightlifting training in early Phase II cardiac rehabilitation will likely assume more importance in the future (McCartney & McKelvie, 1996).

1.5.2.2 Psychological Effects of Weightlifting Training

One of the most beneficial aspects of cardiac exercise rehabilitation may be an improved sense of emotional well-being and self-efficacy. Self-efficacy is defined as one's level of certainty that one can successfully perform a given task or behaviour (Ewart, 1989). As many cardiac patients' perceptions of their physical capabilities (self-efficacy) and inappropriate fears of exertion often exert greater influence over their return to normal activities than does their actual medical or physical status, strategies to increase self-efficacy may be very meaningful (McCartney & McKelvie, 1996). One study in particular has examined the effects of weightlifting training on self-efficacy (Stewart, Mason & Kelemen, 1988). Following 10 weeks of circuit weight training, self-efficacy for tasks requiring significant arm or leg strength increased by 13 and 5.6%, respectively. Self-efficacy for the same tasks in aerobically trained patients decreased by 16 and 20%, respectively. Therefore, because increasing patient self-efficacy can influence which physical activities they attempt, how hard they exert themselves, and how long they are likely to persevere, the addition of weightlifting training in cardiac rehabilitation appears to be an effective way to achieve this important goal (Ewart, 1989).

In conclusion, weightlifting training can provide a safe and effective method for increasing muscular strength and endurance and improving self-efficacy and psychological well-being in cardiac patients, and should be prescribed as a supplement to regular aerobic exercise training in cardiac rehabilitation. Specific safety guidelines for weightlifting training in cardiac patients can be found in several good review articles (Franklin et al., 1991; Kelemen, 1989; McKelvie & McCartney, 1990; Sparling & Cantwell, 1989; Verrill et al., 1992).

1.6 SUMMARY AND STATEMENT OF PURPOSE

Since the early part of the century, physical activity in the rehabilitation of patients following an acute myocardial infarction has gained increasing importance. Studies investigating the benefits of physical training in the management of coronary artery disease began to appear as early as the 1960's and helped to define what is now known as cardiac exercise rehabilitation. While the traditional approach to cardiac rehabilitation involved the prescription of aerobic exercises such as walking and cycling, weightlifting training has recently been demonstrated to be a safe and effective form of exercise in increasing muscle strength, and is now recommended as a supplement to regular aerobic exercise training in many cardiac rehabilitation programs.

Based on the reports of the acute and chronic effects of weightlifting in patients with coronary artery disease, however, there are still gaps in our knowledge of the safety of this form of exercise in cardiac patients. Specifically, little is known about the circulatory response to double-arm exercise and to different modes of weightlifting exercise.

The importance of direct (intra-arterial) methods of blood pressure measurement is now known. However, although previous methods proved useful to investigate the cardiovascular responses to leg and single-arm exercise (Haslam et al., 1988; Wiecek, McCartney & McKelvie, 1990), the response to double-arm exercise could not be measured. Despite this lack of information, double-arm weightlifting exercise is currently being prescribed in many cardiac rehabilitation programs. The cardiovascular response to double-arm weightlifting exercise may be significantly higher than the response to single-arm exercise, however, as arterial pressure increases with the amount of muscle mass activated, although not in a linear fashion (McCartney et al., 1993). Recently, a study was conducted by O'Brien (1994) in healthy young subjects which allowed continuous measurement of arterial pressure during double-arm exercise using a Millar catheter-tip pressure transducer. A comparative study in cardiac patients has not yet been undertaken.

To date, information on the acute responses to arm weightlifting exercise has been collected during lifting on machine weight equipment. Only one previous study has attempted to compare the blood pressure responses during free weight and hydraulic resistive exercise (Freedson et al., 1984). Subjects performed 10 repetitions of bench press free weight exercise at 25 and 50% of maximum isometric strength, and 10 repetitions of bench press hydraulic resistive exercise at fast and slow lifting speeds. The use of the hydraulic equipment, however, prevented proper comparison of the response to the two modes of exercise. It is hypothesized that the pressor response may be greater, however, when lifting with free weights due to the effect of muscle mass, as several accessory muscles may have to be recruited in order to perform the exercise properly. Thus, the arterial pressure response to free weight and equipment weightlifting should be compared, as many cardiac rehabilitation programs only have access to the free weight mode of weightlifting.

This thesis project will attempt to resolve these issues, and to provide recommendations to guide the prescription of arm weightlifting exercise for patients with coronary artery disease.

The purpose of the present study is to investigate the cardiovascular response to double-arm weightlifting exercise in patients with coronary artery disease. A secondary purpose is to compare the responses during free weight and machine equipment weightlifting exercise. The two arm exercises will also allow comparison of the arterial pressure response during exercise in the supine position and exercise in which the weights are lifted over the head.

2.0 METHODS

2.1 SUBJECTS

The subjects included 8 men (mean±SD: age=57.6±10 years, height=172.9 ±3.6 cm, weight=82.0±6.8 kg; Table 1) with well-documented CAD who had been participating in the Chedoke-McMaster Cardiac Exercise Rehabilitation Program for ≥ 8 months before the start of the study. Of the 8 subjects, all had a previous myocardial infarction (1 subject had 2 previous MIs) and 2 had coronary artery bypass graft surgery. Subjects were taking common heart medications, listed in Table 2, which remained unchanged throughout the study. Exclusion criteria included: unstable angina, significant ventricular dysrhythmias, evidence of myocardial dysfunction, previous anterior myocardial infarction, resting diastolic pressure over 95 mmHg, resting systolic pressure over 160 mmHg and a maximal exercise capacity < 6 METS (ACSM, 1988). The procedures and associated risks were described in detail to the patients and they gave signed informed consent prior to their participation in the study. The project was approved by the McMaster University Faculty of Health Sciences and Affiliated Institutions Ethics Committee. The laboratory was equipped with appropriate resuscitation equipment and the study was supervised by a cardiologist at all times.

2.2 EXERCISE PROTOCOL

Within one week prior to the study day, subjects' one repetition maximums (1RM) were measured for the bench press (BP) and overhead press (OP) using both the free weights and the weightstack resistance machine (model 4141-162; Global Gym and Fitness Equipment Limited, Weston, Ontario).

The 1RM was determined by having the subject perform single repetitions with progressively heavier weights, resting one to two minutes between attempts. The heaviest weight that the subject could lift only once was considered to be the 1RM (Table 3).

On the study day the intra-arterial catheter was inserted. The subject performed the following exercises in random order: bench press and overhead press at 40% and 60% of 1RM, using both the free weights and the weightlifting equipment. Weightlifting sets consisted of ten repetitions. Between each exercise the subject rested for two to three minutes or until arterial pressures returned to near pre-exercise levels.

2.3 INTRA-ARTERIAL PRESSURE MEASUREMENT

Intra-arterial pressure was recorded from the subclavian artery of the subject's right arm by a Millar catheter with a pressure sensor at its tip (Millar Mikro-Tip Catheter Transducer, model MPC-500; Millar Instruments, Inc., Houston, Texas). After administration of a subcutaneous local anesthetic (1.0 cc of Xylocaine 2%; Astra Pharmaceuticals Inc., Mississauga, Ontario), the Seldinger technique was used to place a six French percutaneous introducer (Super Arrowflex Percutaneous Sheath Introducer, product CP-07611; Arrow Medical Products Ltd., Mississauga, Ontario) in the brachial artery. The Millar catheter was inserted through the sheath and advanced a pre-measured distance to where the catheter tip would be considered to lie within the subclavian artery. The distance was determined by measuring from the point of incision, up around the curve of the shoulder to the mid-clavicle area. The portion of the catheter remaining outside of the artery and the catheter's connector were securely fixed to the arm to minimize possible movement of the catheter tip during exercise.

The arterial pressure signals were transmitted to a strain gauge bridge amplifier (Accudata 143; Honeywell, Denver, Colorado). Using a computer on-line data acquisition software/hardware package (WINDAQ, Dataq Instruments, Inc., Akron, Ohio), the signals were sampled at a rate of 300 Hz and continously displayed on a computer monitor and saved on the computer hard drive. Upon removal of the Millar catheter after completion of the exercise, the system was calibrated with a mercury manometer by injecting static air pressures of 0 and 100 mmHg into a sealed tube containing the pressure transducer.

2.4 ELECTROCARDIOGRAM MEASUREMENT

A 12-lead electrocardiogram (1515-B Automatic Cardiograph, Hewlett Packard) was recorded at rest and immediately after the completion of each weightlifting set in order to monitor the occurrence of dysrhythmias and ischemic changes with exercise.

2.5 INTRATHORACIC PRESSURE MEASUREMENT

An attempt was made to estimate intrathoracic pressure in order to investigate the use of the Valsalva maneuver during weightlifting. Subjects were instructed to maintain an open glottis while expiring through a mouthpiece against a closed system. Intrathoracic pressure was recorded as mouth pressure by a pressure transducer attached to the mouthpiece. Subjects could not, however, perform this technique properly, and the measurement was therefore discontinued.

2.6 DATA ANALYSIS

During the weightlifting exercises, an event marker was used to designate the beginning and end of each repetition. This allowed the pressure waveforms to be analyzed by repetition. Each pressure waveform was analyzed beat-by-beat using customized WINDAQ software. The program marked the peak and valley of the pressure waveforms, allowing for detection of the peak systolic (PSBP) and diastolic (PDBP) pressures and for the calculation of the average systolic (XSBP) and diastolic (XDBP) pressures and heart rate (HR) on a per repetition basis. The rate-pressure product (RPP) was calculated from the product of the average systolic pressure and average heart rate per repetition. The program also integrated the waveforms over the duration of each repetition and divided the value by the time per repetition to determine the mean arterial pressure (MAP). The diastolic phases of the pressure waveforms were also sectioned and then integrated by the WINDAQ software. Diastole was defined from the inflection point just prior to the dicrotic notch, indicating aortic valve closure, to the inflection point indicating mitral valve closure (Berne & Levy, 1993). The latter was not always evident, at which times the inflection point indicating the aortic valve opening was used and thus necessitated the inclusion of the isovolumetric contraction period of systole into diastole. The duration of this period was minimal, making its inclusion insignificant. The WINDAQ software reported the area under the diastolic pressure curve, which was then multiplied by the heart rate and averaged to determine the diastolic pressure time index (DPTI) per repetition. The DPTI was divided by the RPP to determine the DPTI:RPP ratio (Figure 1).

No pressure adjustments were made to the pressure waveforms for the vertical column effect of the arterial system because the catheter-tip transducer measured subclavian arterial pressure which closely approximates aortic pressure (O'Rourke, Kelly & Avolio, 1992).

2.7 STATISTICAL ANALYSIS

Statistical analysis was accomplished by a 4-factor analysis of variance with repeated measures. The exercise factor consisted of two levels (bench press and overhead press), the mode factor had two levels (equipment and free weight), the intensity factor had two levels (40% and 60%) and the repetitions factor consisted of 11 levels (pre-exercise and repetitions 1-10). A separate ANOVA was done for each of the 9 dependent variables. When a significant interaction occurred ($p<0.05$), a Tukey HSD post hoc test was done to assess the significance of differences among specific means.

3.0 RESULTS

All subjects completed the 1RM testing and weightlifting exercises without dyspnea, chest pain, significant dysrhythmias or ischemic ECG changes. Preliminary 1RM testing results (Figure 2) revealed higher 1RMs when lifting with the machine equipment compared to the free weights for both the overhead press (34.7 vs. 31.9 kg) and bench press (58.2 vs. 46.6 kg) exercises.

A typical arterial pressure trace during lifting (overhead press, equipment, 60% of 1RM) is presented in Figure 3. The highest pressures were reached during the final repetitions of the set, and within 5 seconds of the final lift there was a rapid decrease in both systolic (206 to 161 mmHg) and diastolic (120 to 80 mmHg) pressure. The following results will address the differences between exercises (overhead press and bench press), modes (free weight and machine equipment), intensities (40 and 60%) and repetitions (pre-exercise and repetitions 1-10) for each of the dependent variables measured. Data are reported as means and standard deviations.

3.1 Arterial Pressures

The systolic pressure increased significantly during both of the exercises at both intensities and modes. Significant increases were found between pre-exercise and exercise values and every 3-5 repetitions throughout exercise. The average systolic blood pressure (XSBP) increased from a pre-exercise range of

141±11 mmHg to 153±19 mmHg (mean=146 mmHg) to a range of 164±12 mmHg to 191±18 mmHg (mean=178 mmHg) (Figure 4). The peak systolic blood pressure (PSBP) increased from a pre-exercise range of 142±10 mmHg to 155±18 mmHg (mean=147 mmHg) to a range of 169±13 mmHg to 197±17 mmHg (mean=184 mmHg) (Figure 5). For both the XSBP and PSBP, significant differences were found between exercises, the overhead press showing the higher systolic pressure response. Significant differences were also found between the 40% and 60% intensities. No significant differences were evident between the two modes of exercise.

The diastolic pressure increased significantly during both of the exercises at both intensities and modes. Significant increases were found between pre-exercise and exercise values and every 3-6 repetitions throughout exercise. The average diastolic blood pressure (XDBP) increased from a pre-exercise range of 67±8 mmHg to 80±15 mmHg (mean=75 mmHg) to a range of 91±7 mmHg to 112±15 mmHg (mean=103 mmHg) (Figure 6). The peak diastolic blood pressure (PDBP) increased from a pre-exercise range of 69±8 mmHg to 81±16 mmHg (mean=77 mmHg) to a range of 95±7 mmHg to 119±15 mmHg (mean=107 mmHg) (Figure 7). A significant difference was found between the 40% and 60% intensities for both the XDBP and PDBP. No significant differences were found between exercises or between modes.

The mean arterial pressure (MAP) increased significantly during both of the exercises at both intensities and modes (Figure 8). Significant increases were found between pre-exercise and exercise MAPs and every 2-4 repetitions throughout exercise. MAP increased from a pre-exercise range of 97±8 mmHg to 110±16 mmHg (mean=104 mmHg) to a range of 122±8 mmHg to 147±17 mmHg (mean=135 mmHg). A significant difference was found between the 40% and 60% intensities. MAP did not differ significantly between exercises or between modes.

3.2 Rate-Pressure Product

The rate-pressure product (RPP) increased significantly during both of the exercises at both intensities and modes (Figure 9). Significant increases were found between pre-exercise and exercise RPPs and every 1-4 repetitions throughout exercise. RPP increased from a pre-exercise range of 8985±1903 to 10811±2647 (mean=9643) to a range of 12229±1795 to 18205±3592 (mean=15290). A significant difference was found between exercises, the overhead press showing the higher RPP response. A significant difference was also found between the 40% and 60% intensities. No significant difference was evident between the two modes of exercise.

3.3 Diastolic Pressure Time Index

The diastolic pressure time index (DPTI) increased significantly during both of the exercises at both intensities and modes (Figure 10). Significant increases were found between pre-exercise and exercise values. DPTI increased from a pre-exercise range of 3186±329 mmHg•s•min^{-1} to 3609±493 mmHg•s•min^{-1} (mean=3448 mmHg•s•min^{-1}) to a range of 3776±410 mmHg•s•min^{-1} to 4257±848 mmHg•s•min^{-1} (mean=3926 mmHg•s•min^{-1}). No significant differences were found between each of the two exercises, intensities or modes.

3.4 Diastolic Pressure Time Index to Rate-Pressure Product Ratio

The DPTI:RPP ratio decreased significantly during both of the exercises at both intensities and modes (Figure 11). Significant decreases were evident between pre-exercise and exercise (excluding repetition 1) values and every 5-9 repetitions throughout exercise. DPTI:RPP decreased from a pre-exercise range of 0.3868±.0881 to 0.3426±.0790 (mean=0.3741) to a range of 0.3085±.0537 to 0.2236±.0547 (mean=0.2629). A significant difference was found between exercises, the overhead press showing the largest decrease. A significant difference was also found between the 40% and 60% intensities. No significant difference was evident between the two modes of exercise.

3.5 Heart Rate

The heart rate (HR) increased significantly during both of the exercises at both intensities and modes (Figure 12). Significant increases were evident between pre-exercise and exercise HRs and every 1-6 repetitions throughout exercise. HR increased from a pre-exercise range of 62±12 beats•min^{-1} to 71±13 beats•min^{-1} (mean=66 beats•min^{-1}) to a range of 75±11 beats•min^{-1} to 96±13 beats•min^{-1} (mean=85 beats•min^{-1}). A significant difference was found between exercises, the overhead press showing the higher HR response. The HR was also significantly different between the 40% and 60% intensities. No significant difference was evident between the two modes of exercise.

3.6 Electrocardiogram

No ischemic electrocardiographic changes were found with arm weightlifting exercise. One subject did have supraventricular and ventricular premature beats at rest which did not appear to worsen with exercise and were not accompanied by any symptoms of ischemia.

4.0 DISCUSSION

Exercise training is now widely used in the rehabilitation of patients with coronary artery disease. Until recently, though, exercise rehabilitation included only continuous aerobic exercise involving large muscle groups. This despite the fact that many activities of daily living require significant amounts of muscle strength. It is well known that weightlifting training can be used to increase muscular strength. However, this type of exercise has traditionally been contra-indicated in patients with coronary artery disease due to fears of an inappropriate rise in arterial pressure. Recent studies have demonstrated the safety of this form of exercise in cardiac patients, and it is now used throughout the world in many cardiac exercise rehabilitation programs. Nevertheless, there are still gaps in our knowledge of the safety of weightlifting exercise in cardiac patients. Specifically, little is known about the circulatory response to double-arm exercise and to different modes of weightlifting exercise. Therefore, it was the purpose of this study to investigate the response to double-arm weightlifting exercise and to compare the responses during free weight and machine equipment weightlifting exercise in patients with coronary artery disease.

4.1 SAFETY OF WEIGHTLIFTING EXERCISE - THE ECG RESPONSE

The electrocardiogram (ECG) response during arm weightlifting exercise could not be accurately measured due to the electromyographic activity of the chest muscles during lifting. Therefore, a 12-lead ECG was recorded immediately following each set of arm weightlifting exercise to monitor the occurrence of dysrhythmias and ischemic changes with exercise. No patient demonstrated any ST segment depression or complained of any chest discomfort or angina with weightlifting exercise. One patient did have supraventricular and ventricular premature beats at rest which did not worsen with weightlifting exercise. Six subjects, however, had previously demonstrated myocardial ischemia (ST segment depression, angina, T wave inversion) during maximal cycle ergometer testing. This study confirms the reports of others (Faigenbaum et al., 1990; Ferguson et al., 1981; Haslam et al., 1988) which suggest that fewer ischemic changes occur with weightlifting exercise than during traditional exercise testing.

4.2 CIRCULATORY RESPONSE TO ARM WEIGHTLIFTING EXERCISE

The major significance of the present study is that it is the first to measure the intra-arterial pressure response to double-arm exercise in cardiac patients. As illustrated in Figure 3, and as described by previous investigators (Haslam et al., 1988; Wiecek, McCartney & McKelvie, 1990), arterial pressures change in response to the different phases of each repetition, reach the highest values during the last two repetitions of each set, and immediately decrease below pre-exercise levels upon completion of the exercise before returning to normal. Furthermore, the magnitude of the response changes according to the amount of weight lifted, so that arterial pressures are least when lifting at 40% of 1RM and greatest when lifting at 60% of 1RM (Haslam et al., 1988).

The significant arterial pressure increases that occurred in the present study are indicative of the pressor response that accompanies weightlifting exercise. Weightlifting results in mechanical compression of the blood vessels by the contracting muscles, and elevation of intra-thoracic pressure generated by a Valsalva maneuver, causing a rise in arterial pressure (MacDougall et al., 1992). Furthermore, arm weightlifting exercise results in very little attenuation in total peripheral resistance (TPR) due to minimal vasodilation of the small active arm muscle mass and vasoconstriction of the large inactive leg muscle mass (Rowell, 1993). Thus, the mechanical compression of the muscle vasculature combines with a potent pressor response and a Valsalva response to produce parallel increases in systolic and diastolic pressures during arm weightlifting exercise (MacDougall et al., 1985).

4.3 DOUBLE-ARM WEIGHTLIFTING EXERCISE

Until recently, the intra-arterial pressure response to double-arm exercise could not be measured. Despite this lack of information, double-arm weightlifting exercise is currently being prescribed in many cardiac rehabilitation programs. The circulatory response to double-arm weightlifting exercise may be significantly higher than the response to single-arm exercise, as arterial pressure increases with the amount of muscle mass activiated, although not in a linear fashion (McCartney et al., 1993). Therefore, the purpose of the present study was to investigate the response to double-arm weightlifting exercise in patients with coronary artery disease using the Millar catheter-tip pressure transducer.

The arterial pressure responses to double-arm bench press and overhead press were reported. Mean peak systolic and diastolic arterial pressures recorded during the final repetitions of each weightlifting set did not exceed the value of 250/120 mmHg considered to be acceptable for dynamic exercise (ACSM, 1988). Individual subjects did, however, record diastolic pressures as high as 150 mmHg during one or more of the weightlifting exercises, and individual mean arterial pressures reached values as high as 181 mmHg during overhead press machine equipment exercise at 60% of 1RM.

Single-arm exercise was not included in the present study for two main reasons. The first was that we wanted to minimize the length of time that the catheter remained in the artery in an attempt to prevent possible complications. The second was related to the fact that single-arm bench press and overhead press exercises are difficult to perform properly, and thus, are usually performed with both arms during weightlifting training.

Several studies have examined the circulatory response to arm weightlifting exercise in cardiac patients (Butler, Beierwaltes & Rogers, 1987; Haslam et al., 1988; Sparling et al., 1990; Vander et al., 1986; Wiecek, McCartney & McKelvie, 1990). Vander et al. (1986) reported only small increases in auscultatory systolic and diastolic pressures with upper body Nautilus exercises at 40-60% of 1RM. In similar studies, no change (Sparling et al., 1990) or minimal increases (Butler, Beierwaltes & Rogers, 1987) in systolic and diastolic pressures were reported with arm circuit weight training exercise performed at comparable relative intensities. The problem with these studies, however, was that blood pressure was measured by auscultation immediately after lifting. A recent study by Wiecek, McCartney & McKelvie (1990) comparing direct and indirect measures of arterial pressure concluded that it is not possible to draw conclusions about the pressor response during lifting from measurements made immediately following exercise. Thus, it is important to use intra-arterial methods of blood pressure measurement to investigate the pressor response during weightlifting exercise.

Only two studies have examined the intra-arterial pressure response to arm weightlifting exercise in cardiac patients. Haslam et al. (1988) reported an intra-brachial pressure of 193/119 mmHg during single-arm curl exercise at 80% of 1RM. Wiecek, McCartney & McKelvie (1990) reported even higher increases in intra-brachial pressures during single-arm curl and single-arm military press exercises at only 60% of 1RM.

The intra-brachial pressure measurement method used in these studies proved useful to investigate the pressor response to single-arm exercise. However, with the catheter positioned in the brachial artery, exercise could only be performed by the non-catheterized arm. Thus, the response to double-arm exercise could not be measured. In the present study, the use of the Millar catheter-tip pressure transducer positioned in the subclavian artery allowed continuous measurement of arterial pressure during double-arm weightlifting exercise.

In comparing the response to single-arm overhead press exercise at 40% and 60% of 1RM reported by Wiecek, McCartney & McKelvie (1990) to double-arm overhead press exercise at the same relative intensities reported in the present study, differences appear to exist. Substantially higher peak arterial pressures were reported by Wiecek, McCartney & McKelvie (1990) despite the fact that subjects were performing single-arm as compared to double-arm exercise. For example, single-arm overhead press exercise at 60% of 1RM generated mean peak arterial pressures of 249/152 mmHg compared to pressures of 197/119 mmHg during double-arm exercise. These differences may be due, at least in part, to the different arterial pressure measurement sites (brachial versus subclavian), as the arterial pressure is approximately 30 mmHg higher in the brachial artery compared to the subclavian artery in the upright position due to the hydrostatic column effect (Rowell, 1993). Furthermore, the arterial pressure increases the further it is measured from the heart due to summation of the incident wave from the heart and the reflected wave from the periphery (O'Rourke, Kelly & Avolio, 1992). Thus, the arterial pressures measured in the subclavian artery are probably a much closer estimate of the true aortic pressure during arm weightlifting exercise.

4.4 EXERCISE MODE

Information on the acute responses to arm weightlifting exercise has typically been collected during lifting on machine weight equipment, yet many cardiac rehabilitation programs only have access to free weights. This study compared the responses during free weight and machine equipment weightlifting exercise. It was hypothesized that the circulatory responses may be greater during free weight lifting due to the effect of muscle mass, as several accessory muscles may have had to be recruited in order to perform the exercise properly. On the other hand, it has previously been demonstrated that the pressor response to weightlifting exercise is tightly coupled to the relative intensity of effort, or percent of 1 repetition maximum (MacDougall et al., 1985; Sale et al., 1993).

Preliminary 1RM testing revealed differences between the two modes of exercise (Figure 2). Subject 1RMs were higher during lifting with the machine equipment compared to free weights for both the overhead press and bench press. Despite these differences in weight lifted, the circulatory responses to the two modes of exercise during weightlifting at the same relative intensity were not significantly different (Figures 4-12). In other words, the circulatory responses at a given percent of 1RM were similar during lifting with the machine equipment and the free weights, even though the amount of weight lifted was more for the machine equipment mode of exercise. These results lend support to the hypothesis that the circulatory response to weightlifting exercise is dependent on the relative intensity of effort, or percent of 1RM, rather than on the actual force developed or weight lifted. In terms of the safety of weightlifting training in cardiac rehabilitation, these results suggest that 1RM testing should be done using the apparatus (free weight or machine equipment) on which the weightlifting training will be performed.

4.5 SUPINE VERSUS UPRIGHT EXERCISE

Exercise in the supine position is much more stressful to the heart than exercise performed in the upright position (Clausen, 1976). Patients with coronary artery disease typically demonstrate a reduced anginal threshold with supine exercise (Bygdeman & Wahren, 1974; Clausen, 1976; Thadani et al., 1977).

This decrease in tolerance with supine exercise has been suggested to be the result of an increased heart volume related to a higher left ventricular filling pressure during exercise in the supine position (Bygdeman & Wahren, 1974). An increased end-diastolic volume augments ventricular wall tension (preload) and thereby raises myocardial oxygen consumption (demand). Furthermore, the increased wall tension tends to reduce myocardial perfusion by increasing the resistance to coronary blood flow during diastole (Bygdeman & Wahren, 1974; Clausen, 1976). Thus, with supine exercise, the augmented filling pressure increases heart volume, augmenting myocardial oxygen requirements, and compromises coronary perfusion, reducing myocardial oxygen supply, thereby precipitating angina and reducing patient exercise tolerance.

The two weightlifting exercises performed in the present study allowed comparison of the circulatory response to exercise in the supine (bench press) and upright (overhead press) positions. No patient demonstrated any evidence of ischemia (ST segment depression) or complained of any angina pain with weightlifting exercise in either the supine or upright positions. Furthermore, contrary to the suggestions just presented, estimates of myocardial oxygen demand were lower and the supply to demand relationship more favourable during supine as compared to upright exercise. The higher myocardial oxygen demand (rate-pressure product) with upright (overhead press) exercise reported in the present study, however, may have been partially due to the effect of muscle mass, as subjects probably had to recruit many more accessory leg, hip and trunk muscles in order to stabilize the torso during overhead lifting. It is recognized that the differences in stabilization afforded by the actual weightlifting benches made the comparison between supine and upright exercise difficult. Differences may also exist between body position and exercise type (dynamic versus weightlifting exercise) which have yet to be examined. Nevertheless, based on the results of the present study, it appears that exercise performed in the supine position may be safer for patients with coronary artery disease than once thought.

4.6 MYOCARDIAL OXYGEN SUPPLY AND DEMAND

The supply of oxygen to the myocardium during exercise is achieved primarily through an increase in myocardial blood flow because of the already high oxygen extraction of the myocardium at rest (Hoffman, 1978). Perfusion of the myocardium, especially the subendocardium, occurs mainly during diastole, as the compressive forces during systole impede coronary blood flow (Baird et al., 1970). Thus, the perfusion pressure during diastole and the duration of diastole can be used to estimate myocardial oxygen supply (Buckberg, Fixler & Archie, 1972). Perfusion pressure, measured as the area between the aortic and left ventricular pressure curves over the duration of diastole, multiplied by the heart rate, has been termed the diastolic pressure time index (DPTI) (Hoffman, 1978). In the present study, the DPTI was used as an estimate of myocardial oxygen supply, and was calculated as the area under the subclavian arterial pressure curve during diastole multiplied by the heart rate. It was assumed that subclavian arterial pressure closely approximated aortic pressure (O'Rourke, Kelly & Avolio, 1992), and that left ventricular end-diastolic pressure did not increase significantly in our subjects, all of whom had adequate ventricular function at rest and had no clinical evidence of depressed ventricular function during exercise (Featherstone, Holly & Amsterdam, 1993).

Myocardial oxygen demand can be estimated from measurements of the heart's oxygen consumption. Several predictors of myocardial oxygen consumption have been examined including the tension-time index, myocardial blood flow, heart rate, double product (heart rate • systolic blood pressure) and triple product (heart rate • systolic blood pressure • ejection time) (Gobel et al., 1978; Kitamura et al., 1972; Nelson et al., 1974). Of these indices, myocardial oxygen consumption correlated best with the product of heart rate and blood pressure (Gobel et al., 1978; Nelson et al., 1974). Consequently, the rate-pressure product was used in the present study as a predictor of myocardial oxygen demand.

The myocardial oxygen supply to demand relationship can be estimated from the ratio of the diastolic pressure time index to the rate-pressure product (DPTI:RPP). A lower ratio would be associated with a decreased coronary blood flow during diastole and also with a decreased proportion of blood flow to the subendocardium, the potential result being myocardial (subendocardial) ischemia. On the other hand, the higher the ratio, the more likely there is adequate subendocardial perfusion (Hoffman, 1978).

The present study investigated myocardial oxygen supply (DPTI) and demand (RPP) during double-arm weightlifting exercise in patients with coronary artery disease. As expected, myocardial oxygen demand (RPP) increased significantly during both of the exercises at both intensities and modes due to significant increases in both heart rate and systolic blood pressure. The DPTI also increased with arm weightlifting exercise suggesting improved myocardial oxygen supply. However, because of the proportionately larger increase in RPP compared to DPTI, the ratio of oxygen supply to demand decreased with arm weightlifting exercise.

Compared to the results of the present study, Featherstone, Holly & Amsterdam (1993) reported similar (40% of 1RM) or lower (60% of 1RM) rate-pressure products for the same exercises as performed in the present study. The lower RPPs reported with arm weightlifting exercise at 60% of 1RM may be related to a lower myocardial oxygen demand during single-arm as compared to double-arm exercise. These differences may be partially negated, however, due to the fact that Featherstone's subjects performed weightlifting exercise to fatigue. Several other reports of rate-pressure product during arm weightlifting exercise have suggested much lower myocardial oxygen demands with similar exercises at comparable training intensities (Butler, Beierwaltes & Rogers, 1987; Crozier Ghilarducci, Holly & Amsterdam, 1989; Vander et al., 1986). These differences are most likely due to the indirect technique used to measure arterial pressure. Thus, the RPPs in these earlier reports may have underestimated the demands of weightlifting.

The diastolic pressure time index (DPTI) increased with arm weightlifting exercise suggesting greater coronary perfusion. Featherstone, Holly & Amsterdam (1993) also reported increases in DPTI, however peak DPTIs were considerably lower than those reported here. Again, the differences between reports may originate from the technique used to measure arterial pressure. The auscultatory method, used in the earlier report, allowed calculation of the DPTI as the product of diastolic blood pressure, diastolic time interval and heart rate. The diastolic blood pressure was, however, only a single value equal to the lowest point on the arterial pressure curve. With intra-arterial pressure measurement, the DPTI was calculated more precisely by integrating the entire diastolic pressure curve, and therefore, the mean pressure during diastole was used in calculating the DPTI. Thus, the myocardial oxygen supply may have also been underestimated in the earlier report.

The DPTI:RPP ratio indicated that the myocardial oxygen supply to demand balance decreased with arm weightlifting exercise. Ratios were even lower in an earlier published report (Featherstone, Holly & Amsterdam, 1993), most likely due to the underestimation of both the RPP and the DPTI with auscultatory blood pressure measurement. When compared to dynamic treadmill exercise, however, the DPTI:RPP ratio was more favourable during weightlifting (Featherstone, Holly & Amsterdam, 1993). While subjects in the present study did not perform dynamic exercise, their results can be compared to previous indirectly measured cycle ergometer testing values. The diastolic pressure response to weightlifting (107 mmHg) was much greater than during cycle ergometer exercise (76 mmHg), whereas systolic pressures were similar (184 mmHg and 183 mmHg during weightlifting and cycling, respectively). Although, had arterial pressure been measured directly during cycle ergometer testing, systolic pressures would have been higher than those recorded during weightlifting, as systolic blood pressure is typically underestimated by 15% using indirect methods (Wiecek, McCartney & McKelvie, 1990). The heart rate response was lower during weightlifting (85 beats•min^{-1} as compared to 128 beats•min^{-1} during cycling) with an accompanying lower rate-pressure product (15290 as compared to 23618 during cycling) reflecting a lower myocardial oxygen requirement. Furthermore, as coronary blood flow occurs mainly during diastole, the slower heart rate (longer diastolic time period) and higher diastolic pressure (increased coronary perfusion pressure) associated with weightlifting (McCartney & McKelvie, 1996) would improve myocardial oxygen supply. Thus, although the DPTI:RPP ratio decreased with arm weightlifting exercise, the myocardial oxygen supply to demand balance is likely to be substantially more favourable during weightlifting compared to maximal cycle ergometer exercise testing.

4.7 SUMMARY AND RECOMMENDATIONS

The major significance of this study is that it is the first to measure intra-subclavian pressures during weightlifting exercise in patients with coronary artery disease. The circulatory response to double-arm weightlifting during both machine equipment and free weight modes of lifting were reported. Systolic and diastolic pressures rose in parallel with both modes of lifting, while heart rate did not increase substantially. Pressures did not, however, exceed values considered to be acceptable for dynamic exercise. Furthermore, while the high arterial pressures associated with weightlifting increased myocardial oxygen demand, the increase in diastolic pressure may have augmented oxygen supply. However, because of the proportionately larger increase in RPP compared to DPTI, the ratio of oxygen supply to demand decreased with arm weightlifting exercise. Nevertheless, the estimated myocardial oxygen supply to demand relationship appears to be more favourable during double-arm weightlifting exercise compared to maximal cycle ergometer testing in this aerobically trained group of cardiac patients. These results suggest that double-arm weightlifting exercise at 40 to 60% of 1RM is safe and appropriate for patients with coronary artery disease and can be performed using either free weights or machine weightlifting equipment.

Based on the results of this thesis study, new recommendations can be made to guide the prescription of arm weightlifting exercise for patients with coronary artery disease.

1. Double-arm weightlifting exercise is safe and appropriate in patients with coronary artery disease and may be incorporated into a weightlifting training program.

2. Double-arm weightlifting exercises should be limited to 60% of 1RM as intensities greater than this may produce unacceptable increases in arterial pressure and rate-pressure product and decreases in the diastolic pressure time index to rate-pressure product ratio.

3. Weightlifting may be performed with machine equipment or free weights. However, machines are preferable to free weights because they are safer, easier to learn and do not require the use of a spotter.

4. 1RM testing must be done using the mode of exercise (machine equipment or free weight) on which the weightlifting training will be performed.

Weightlifting training is a safe and effective form of exercise in increasing muscular strength and endurance in patients with coronary artery disease. Arm weightlifting training may be particularly important as many activities of daily living are performed by the arms and require significant amounts of upper body strength. Furthermore, many of these activities frequently demand a combination of static and dynamic effort. Therefore, arm weightlifting training should play an important role in the rehabilitation of patients with coronary artery disease.

TABLE 1 SUBJECT CHARACTERISTICS

SUBJECT	AGE (years)	HEIGHT (cm)	WEIGHT (kg)
1	61	173	80
2	65	168	81.8
3	57	173	82
4	71	171	76
5	38	180	89
6	58	170	71
7	50	173	92.3
8	61	175	84
Mean	58	173	82
SD	10.0	3.6	6.8

TABLE 2 SUBJECT MEDICATIONS

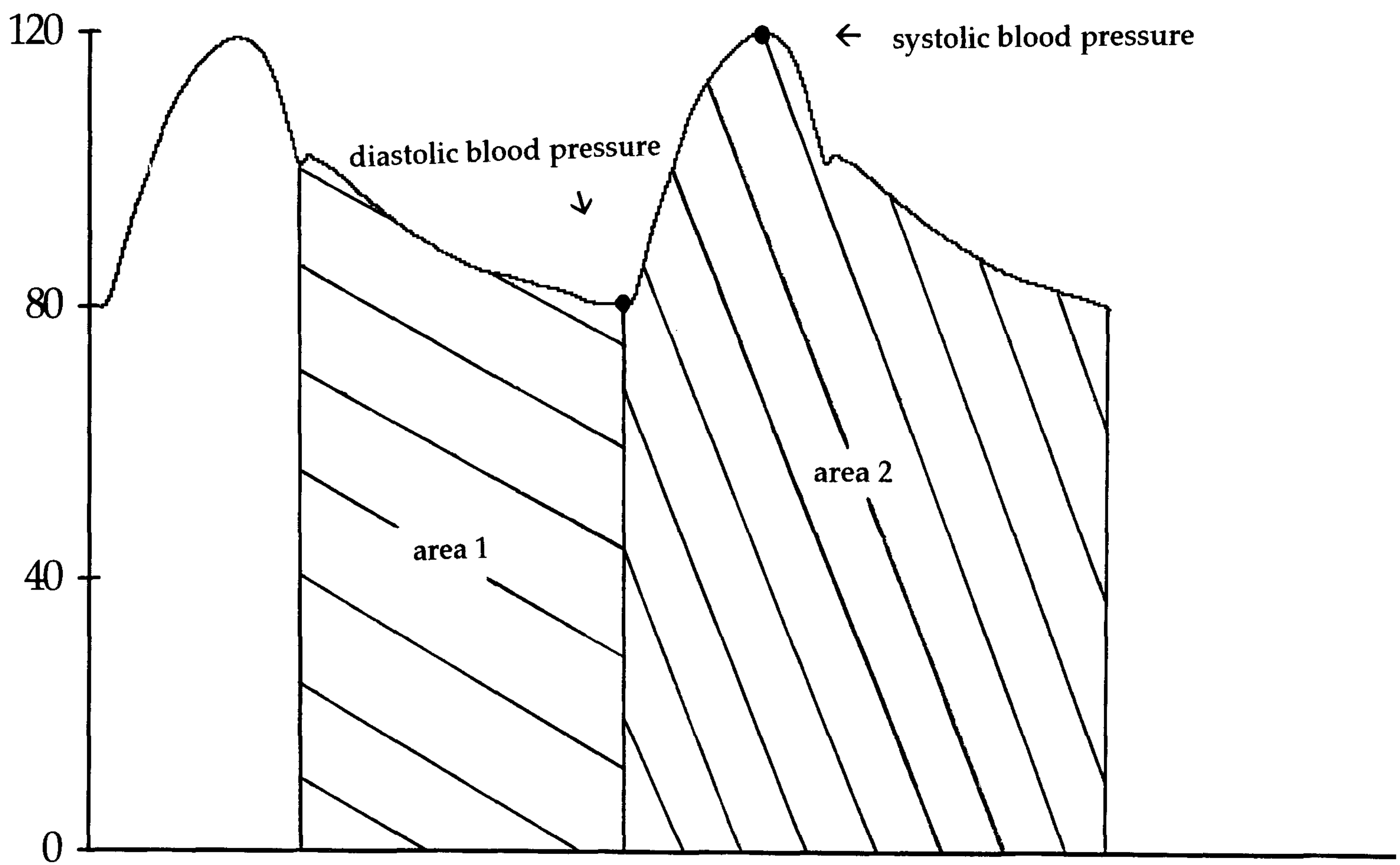
MEDICATIONS	NUMBER OF SUBJECTS
ASA	6
BETA-BLOCKERS	5
CALCIUM CHANNEL BLOCKERS	1
NITRATES	1
ACE INHIBITORS	1
HYPERLIPIDEMIC AGENTS	3

TABLE 3 SUBJECT 1 REPETITION MAXIMUMS (KG)
BP=BENCH PRESS OP=OVERHEAD PRESS

SUBJECT	BP EQUIPMENT	BP FREE	OP EQUIPMENT	OP FREE
1	52.5	40.9	30	27.3
2	46.3	38.6	23.8	25
3	62.5	56.8	37.5	40.9
4	54	47.7	26.3	25
5	77.5	61.4	50	38.6
6	42.5	29.5	28	23.6
7	70	47.7	42	38.6
8	60	50	40	36.4
Mean	58.2	46.6	34.7	31.9
SD	11.8	10.2	9.1	7.3

FIGURE LEGENDS

Figure 1	Resting arterial pressure trace.
Figure 2	Subject 1 repetition maximums for the overhead press and bench press using both the equipment and free weight modes of weightlifting.
Figure 3	Arterial pressure trace during 10 repetitions of an overhead press at 60% of 1RM using the machine equipment mode of exercise. Double event markers indicate the beginning and end of the set and single event markers indicate the end of each repetition.
Figure 4	Mean systolic blood pressure Top: Bench press. Bottom: Overhead press. Mean systolic blood pressure at 40% (left) and 60% (right) of 1RM prior to exercise (pre) and during repetitions 1-10 of a weightlifting set using the equipment (○) and free weight (■) modes of lifting.
Figure 5	Peak systolic blood pressure. Details as in Figure 4.
Figure 6	Mean diastolic blood pressure. Details as in Figure 4.
Figure 7	Peak diastolic blood pressure. Details as in Figure 4.
Figure 8	Mean arterial pressure. Details as in Figure 4.
Figure 9	Rate-pressure product. Details as in Figure 4.
Figure 10	Diastolic pressure time index. Details as in Figure 4.
Figure 11	Diastolic pressure time index to rate-pressure product ratio. Details as in Figure 4.
Figure 12	Heart rate. Details as in Figure 4.



diastolic pressure time index = area 1 x heart rate

mean arterial pressure = area 2 ÷ base

FIGURE 1 RESTING ARTERIAL PRESSURE TRACE (mmHg)

FIGURE 2 SUBJECT 1 REPETITION MAXIMUMS (KG)

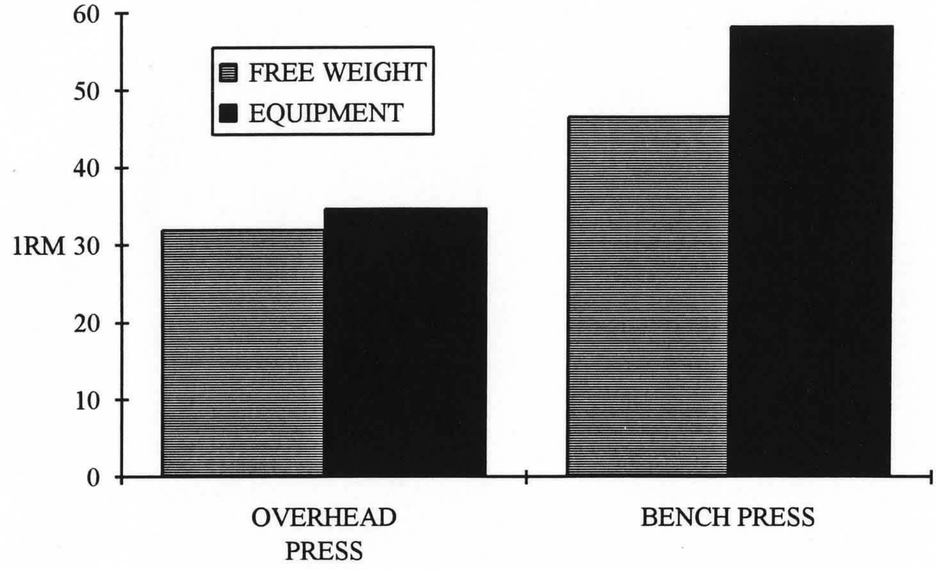


FIGURE 3 EXERCISE ARTERIAL PRESSURE TRACE (mmHg)

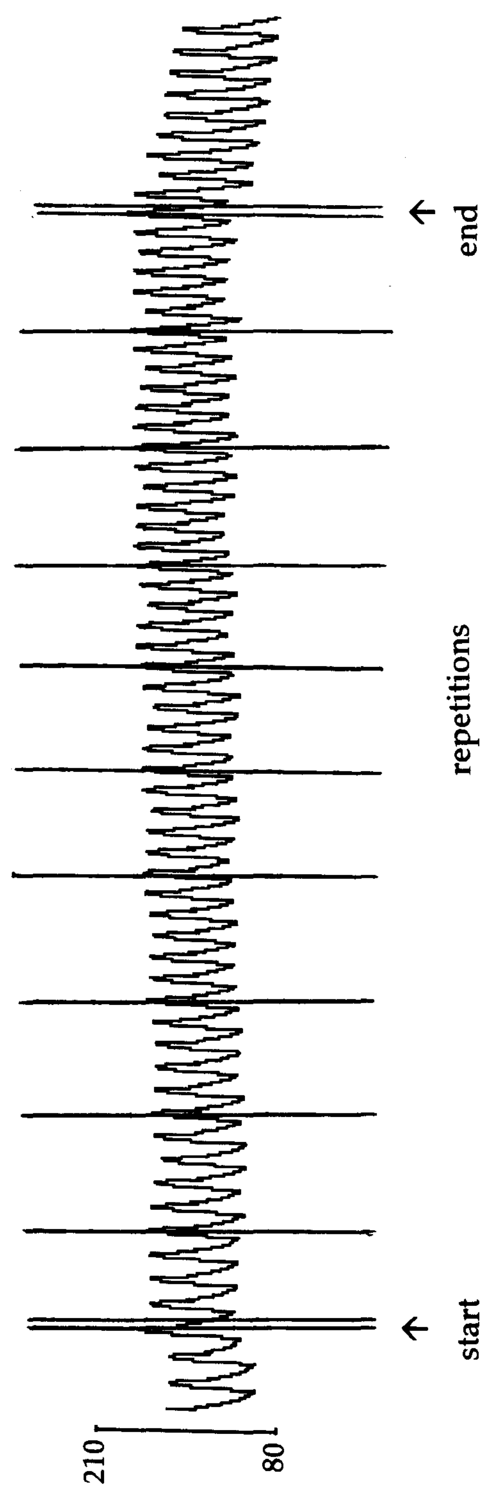
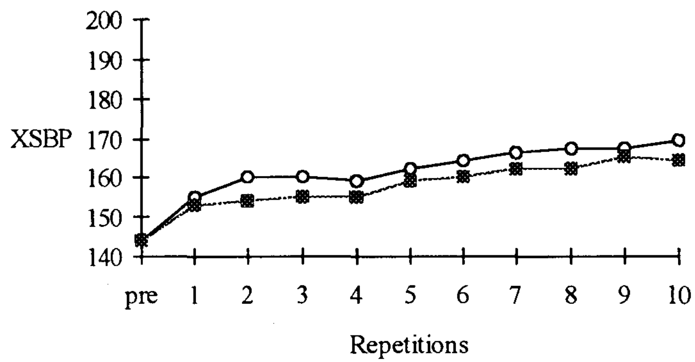
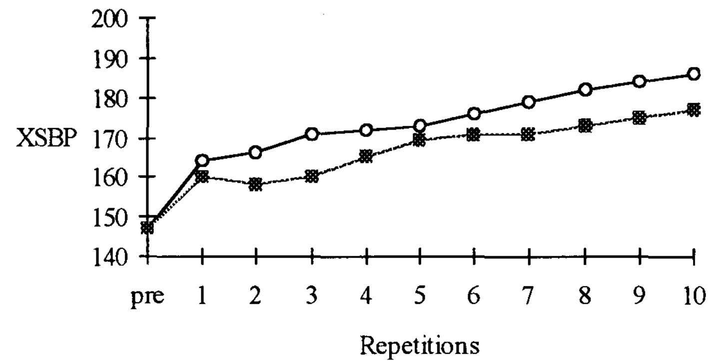


FIGURE 4 MEAN SYSTOLIC BLOOD PRESSURE (mmHg)

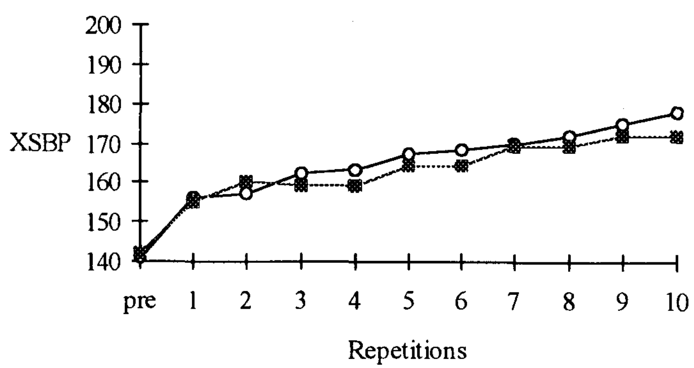
Bench press 40%



Bench press 60%



Overhead press 40%



Overhead press 60%

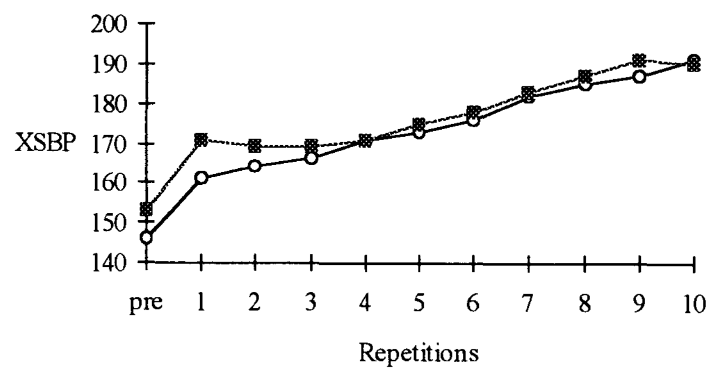


FIGURE 5 PEAK SYSTOLIC BLOOD PRESSURE (mmHg)

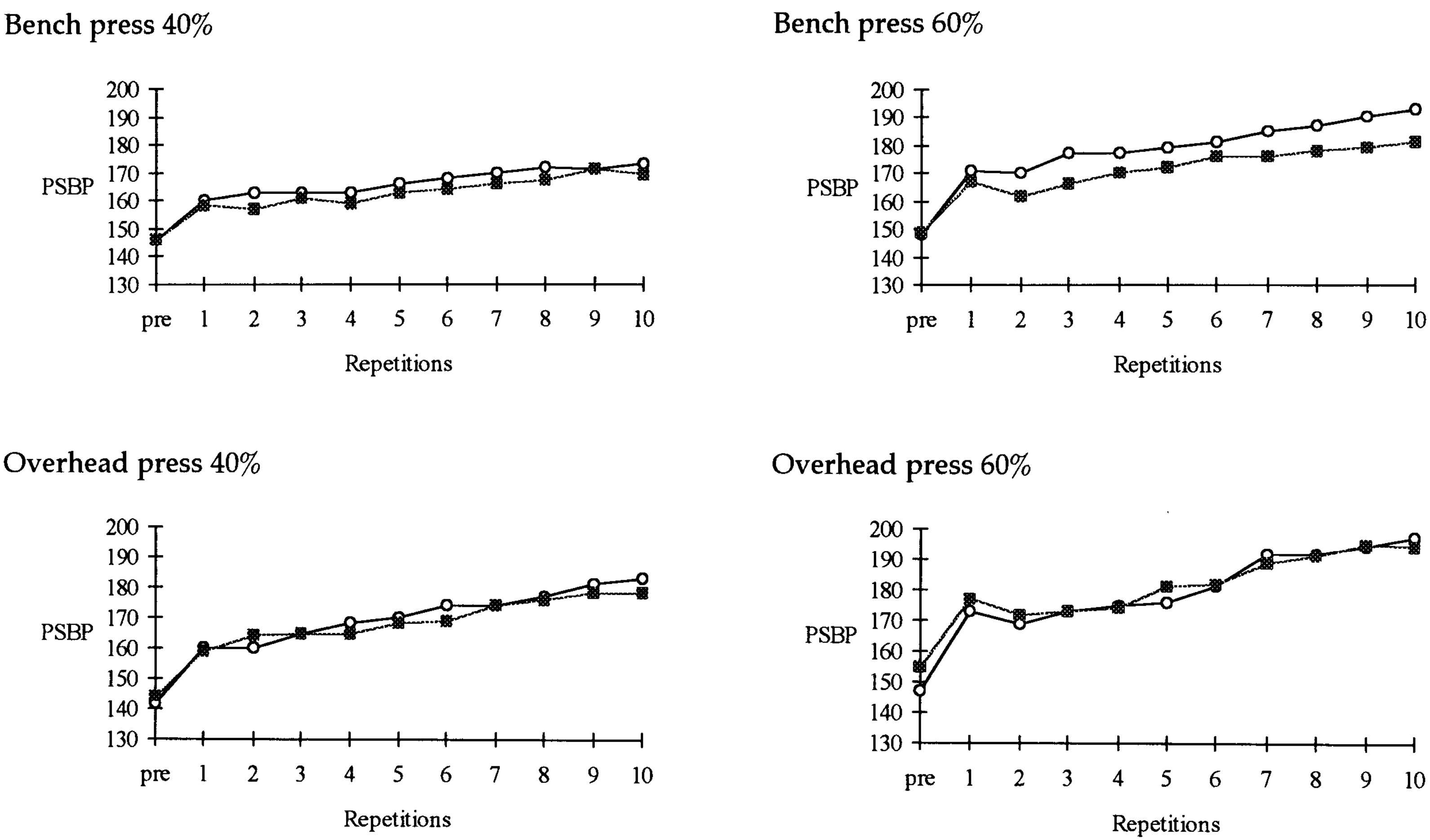


FIGURE 6 MEAN DIASTOLIC BLOOD PRESSURE (mmHg)

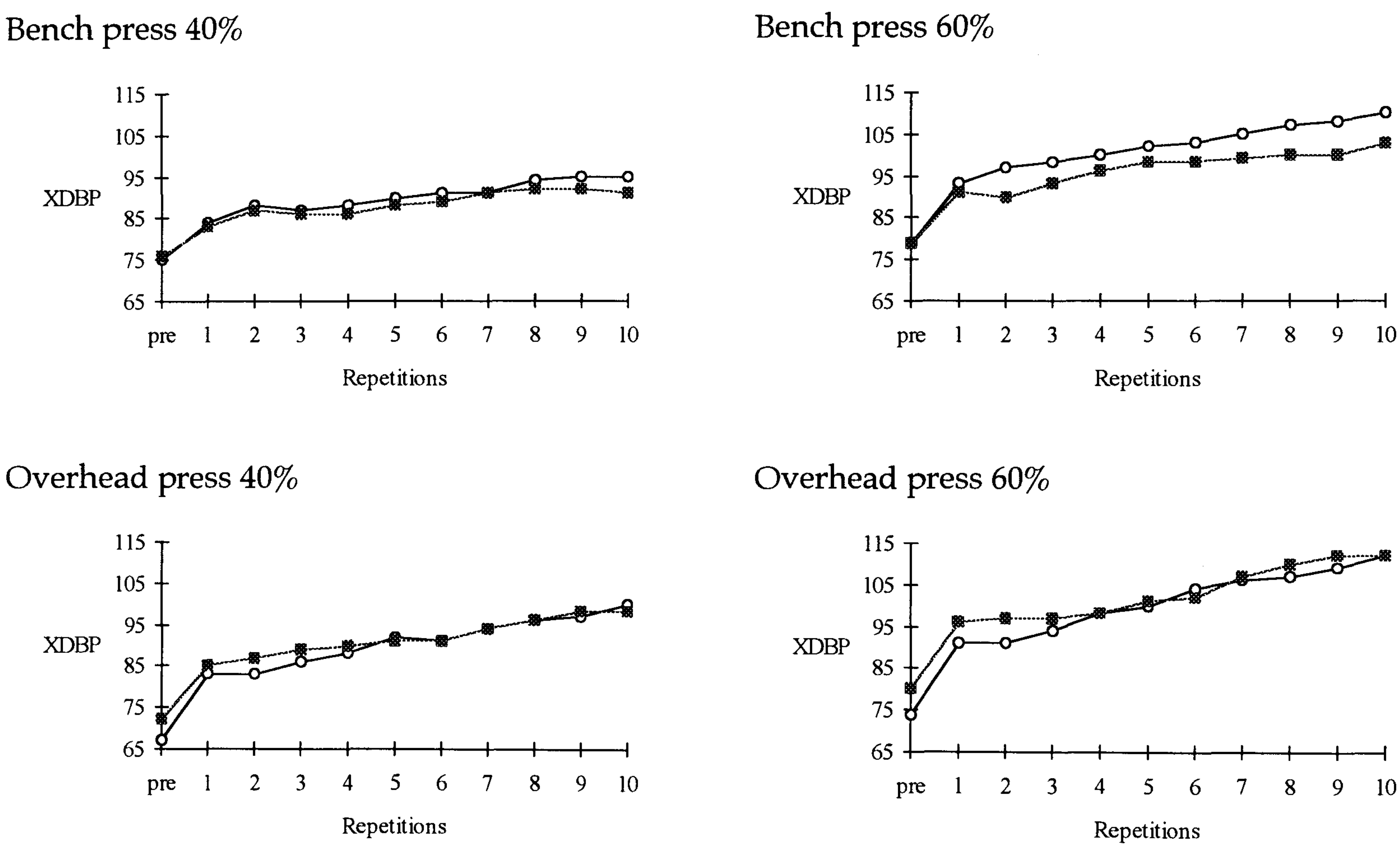
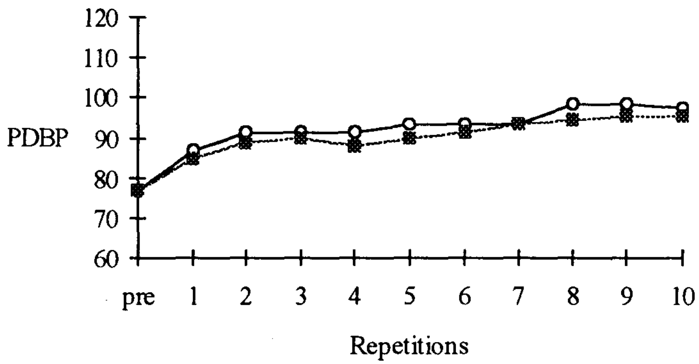
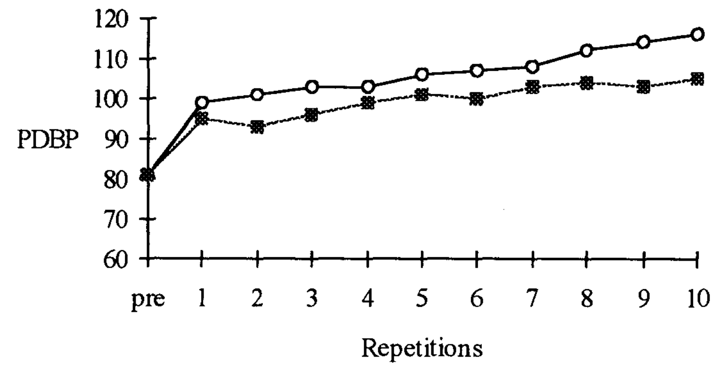


FIGURE 7 PEAK DIASTOLIC BLOOD PRESSURE (mmHg)

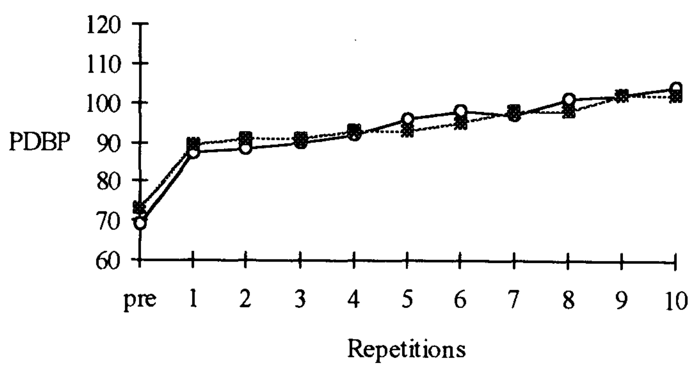
Bench press 40%



Bench press 60%



Overhead press 40%



Overhead press 60%

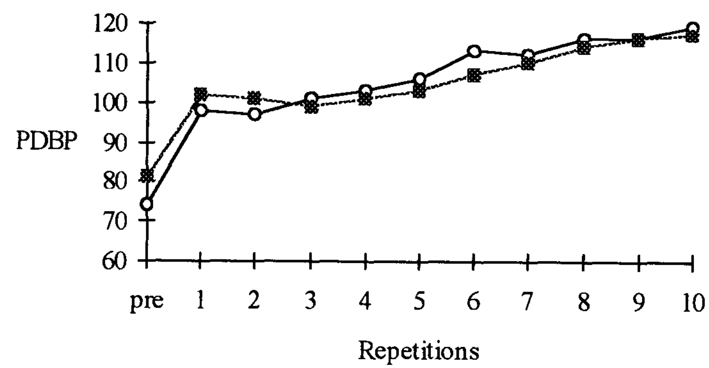
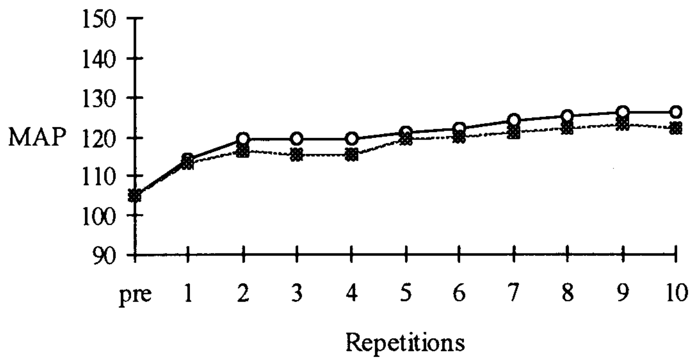
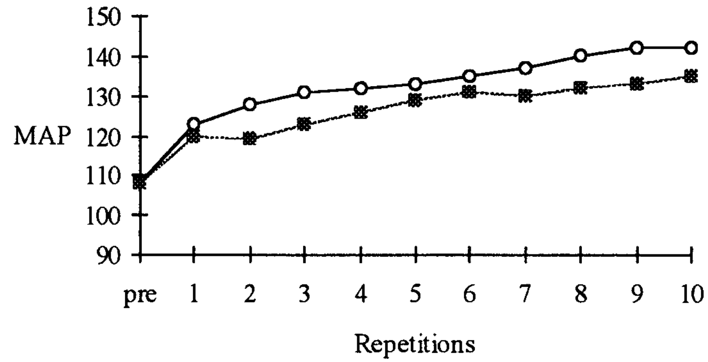


FIGURE 8 MEAN ARTERIAL PRESSURE (mmHg)

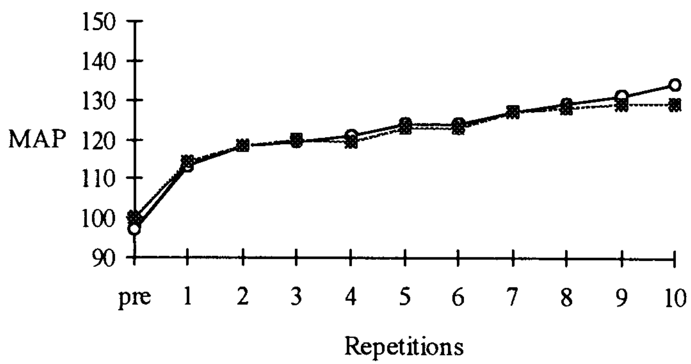
Bench press 40%



Bench press 60%



Overhead press 40%



Overhead press 60%

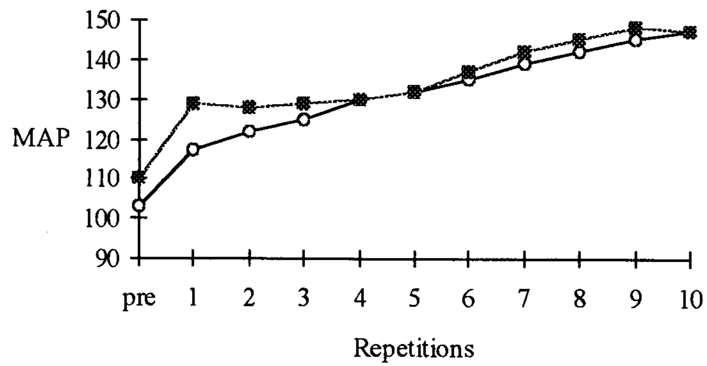
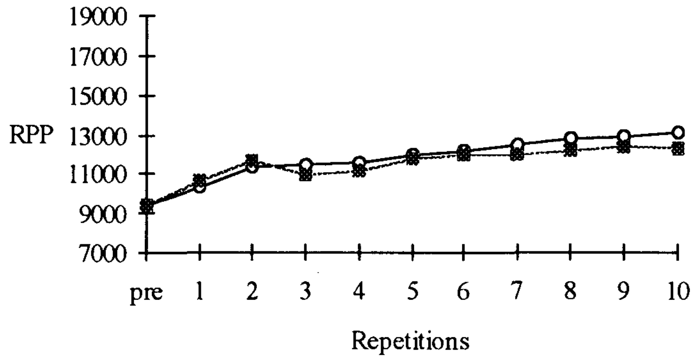
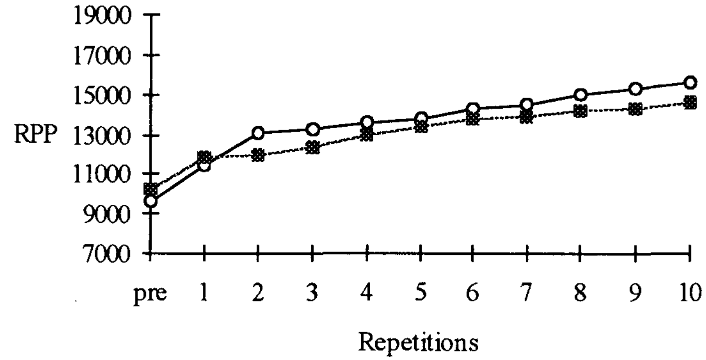


FIGURE 9 RATE-PRESSURE PRODUCT

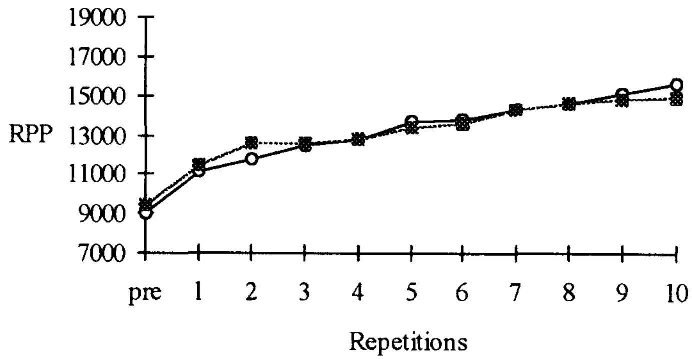
Bench press 40%



Bench press 60%



Overhead press 40%



Overhead press 60%

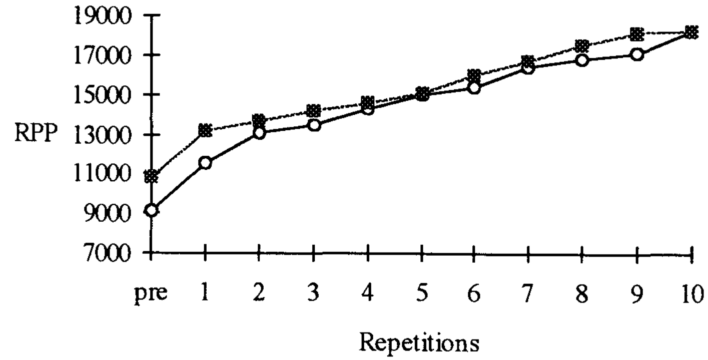
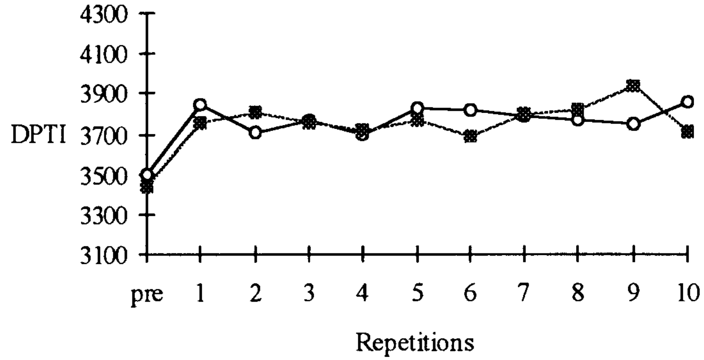
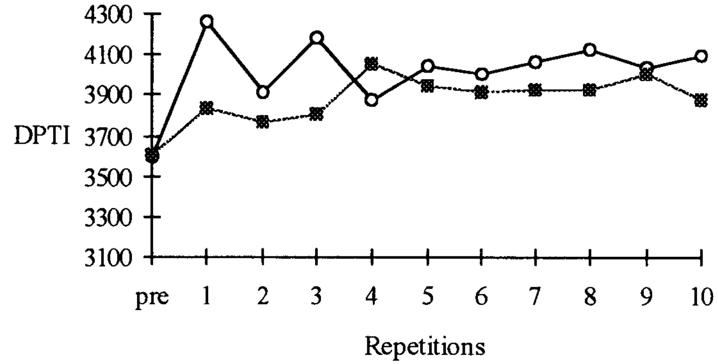


FIGURE 10 DIASTOLIC PRESSURE TIME INDEX (mmHg•s•min^{-1})

Bench press 40%



Bench press 60%



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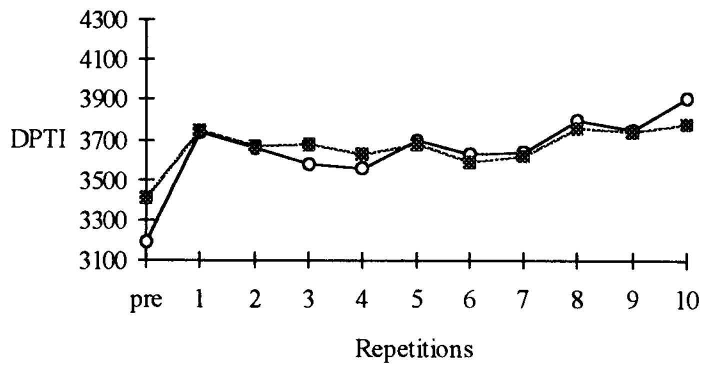


Overhead press 60%

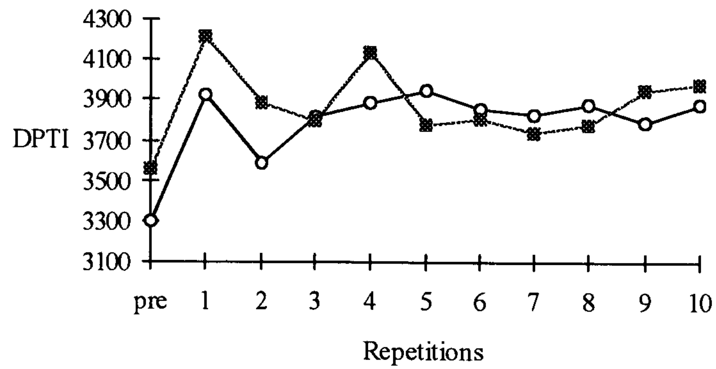
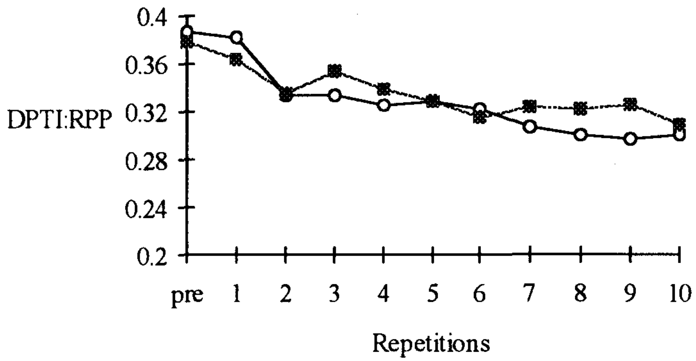
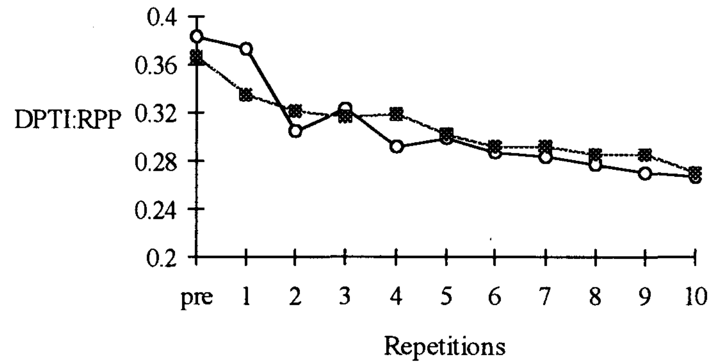


FIGURE 11 DIASTOLIC PRESSURE TIME INDEX TO RATE-PRESSURE PRODUCT RATIO

Bench press 40%



Bench press 60%



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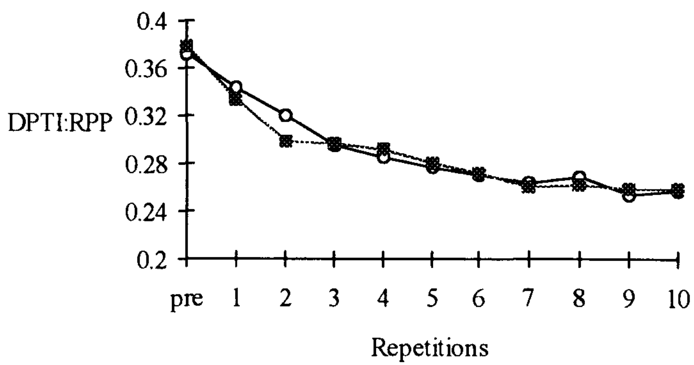


Overhead press 60%

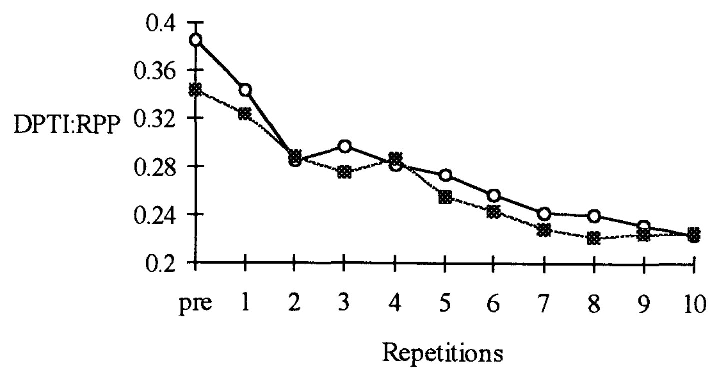
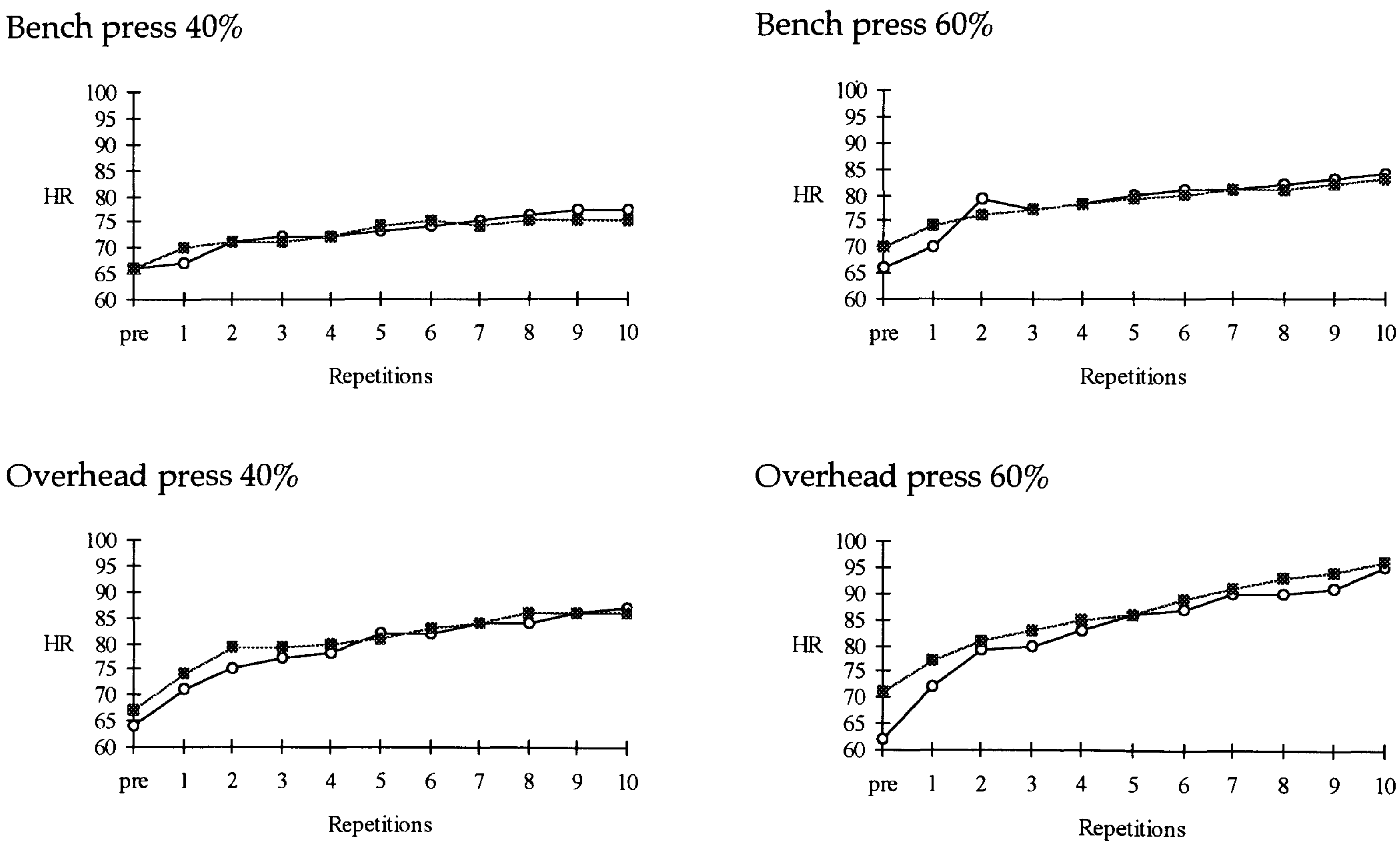


FIGURE 12 HEART RATE (beats•min^{-1})



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APPENDIX A

CONSENT FORM

McMASTER UNIVERSITY
Department of Kinesiology
1280 Main Street West, Hamilton, ON L8S 4K1
Telephone: (905) 525-9140
FAX: (905) 523-6011

CONSENT FORM
Intra-arterial Blood Pressure During Arm Weightlifting Exercise in Male Cardiac Patients

I, ________________________, consent to take part in a study conducted by Dr. N. McCartney, Dr. R.S. McKelvie and L. Hodge, which will examine the effects of arm weightlifting exercise on arterial blood pressure. The purpose of this study is to a) evaluate the effects of this type of exercise on the heart and b) learn more about the best type of arm exercises for cardiac patients.

I have been informed that I will be asked to perform ten repetitions each of two arm weightlifting exercises (bench press and overhead press) at 2 submaximal intensities (40% and 60% of the maximum amount I can lift once), which we have previously established to be safe and appropriate. I will be asked to perform these exercises twice: once using free weights and once using equipment.

A small tube (arterial catheter) will be inserted into the artery of my right arm. A sterilized fine wire will be advanced through the tube and into the artery. The tip will be positioned in the artery of my shoulder. I have been informed that the catheter and fine wire will be inserted by Dr. McKelvie and will remain in place throughout the exercise procedure. Out of approximately twenty procedures that have been done in this laboratory, there have been no instances where the catheter or wire have broken or become dislodged.

There may be slight bruising from the arterial catheter in my arm, but this will disappear in a few days. I have also been made aware and understand that there is a risk of a blood clot in the hand related to the arterial catheter. In rare circumstances this could result in severe, permanent damage to the hand including the loss of a finger. A published survey of complications from arterial catheterizations found a one in one thousand (1/1000) chance of a blood clot developing when the catheter was left in place for twenty-four hours. When this complication occurred there was always complete resolution of the blood clot without residual damage. In our experience, when the catheter has been in place for only a few hours, there has not been any complication related to a blood clot. The risk of a blood clot is minimized by the short duration that the catheter will be in place and the use of an anti-clotting agent, heparin. I also understand that there is risk of an infection related to the catheterization of the artery and this could result in a generalized infection of the body. However this is only a very small potential risk as a recent survey did not find evidence of infection nor have any of the previous subjects in this laboratory suffered this complication.

I understand there is a risk of having a heart attack (approximately 1/750,000 patient hours) or collapsing while exercising, but this risk is very small. I understand that emergency equipment is available at all times in the laboratory and that Dr. McKelvie will always be present should such an event happen. If I have any problems after the test is completed, I have been informed that I can contact Dr. McKelvie by phoning him at his office at Hamilton General Hospital at 572-7155.

If I have any concerns regarding this study or the method by which it was conducted, I am aware that I can report it to the Committee for Ethics for Research of the Faculty of Health Sciences and Affiliated Institutions at McMaster University in person at HSC 3N or by phone at 521-2100, ext. 6017.

I understand that I may withdraw from the study at any time, even after signing this form, without prejudice. Any information that is collected about me during this study will be kept confidential and if the results are published, I will not be identified in any way. If I wish, the results of my test will be made available to me.

Name (print)	Signature	Date
Witness (print)	Signature	Date

I have explained the nature of the study to the subject and believe that he has understood it.

Name (print)	Signature	Date

APPENDIX B

STUDY DATA

BENCH PRESS EQUIPMENT 40%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	165	191	181	181	172	185	187	194	197	198	198
2	132	126	137	141	148	147	154	155	166	166	155
3	159	162	166	163	167	168	169	170	171	171	169
4	114	128	141	139	138	147	136	138	146	135	145
5	152	166	172	172	169	167	168	168	163	161	164
6	152	153	165	162	160	165	176	178	171	179	184
7	135	174	172	173	175	175	170	175	177	177	187
8	163	176	169	172	175	178	181	183	183	183	183
Mean	146	160	163	163	163	166	168	170	172	171	173
SD	18	23	16	15	14	14	16	17	15	18	18

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	79	95	97	98	90	97	98	102	107	108	110
2	65	66	71	75	79	81	84	84	106	106	94
3	79	89	90	90	90	92	94	95	96	96	98
4	57	68	73	72	75	77	72	71	77	76	75
5	86	98	100	102	100	99	100	99	96	96	98
6	80	83	92	89	86	93	95	93	99	97	99
7	73	102	99	95	96	101	99	93	94	102	102
8	95	98	95	97	100	103	105	104	106	106	104
Mean	77	87	90	90	90	93	93	93	98	98	97
SD	12	14	11	11	9	9	11	11	10	10	10

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	164	181	178	174	166	173	181	184	187	192	192
2	128	123	136	140	147	146	151	151	159	161	153
3	157	162	163	161	163	163	165	166	168	167	167
4	113	128	140	138	138	145	134	137	146	135	139
5	150	165	169	170	167	164	167	165	161	159	163
6	149	152	162	160	154	161	170	172	165	173	176
7	132	162	166	167	169	165	162	171	172	170	180
8	159	165	165	167	171	177	180	178	179	180	180
Mean	144	155	160	160	159	162	164	166	167	167	169
SD	18	20	14	14	12	11	15	15	13	17	17

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	78	93	95	95	87	91	97	99	102	106	107
2	64	64	70	75	78	80	83	84	96	96	89
3	78	84	89	88	88	90	92	92	94	93	94
4	56	67	73	72	75	76	70	71	76	76	74
5	85	96	98	98	98	97	99	96	94	95	97
6	78	80	88	87	84	90	93	93	95	95	98
7	68	92	94	89	93	92	91	90	90	95	100
8	95	93	93	95	98	102	103	101	103	103	102
Mean	75	84	88	87	88	90	91	91	94	95	95
SD	12	12	11	9	9	8	10	10	9	9	10

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	113	125	129	128	120	125	131	133	137	141	140
2	91	90	101	105	110	110	114	117	123	122	116
3	109	117	119	118	119	121	122	123	125	124	123
4	81	97	103	100	103	106	97	100	104	101	101
5	114	127	130	130	128	128	129	128	125	125	128
6	109	114	121	119	116	122	128	129	127	130	133
7	101	122	124	125	124	120	121	128	128	128	135
8	121	122	124	125	129	134	135	134	136	135	135
Mean	105	114	119	119	119	121	122	124	125	126	126
SD	13	14	11	11	9	9	12	11	10	12	13

BENCH PRESS EQUIPMENT 40%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7771	9113	11016	10767	10405	10927	11337	11619	12144	12628	12455
2	7921	7787	9448	10189	11112	11295	11681	12049	12974	13143	12303
3	8134	9117	10029	10291	10612	10641	10893	11149	11369	11460	11611
4	7689	8609	9363	9327	9315	9725	9016	9543	10064	9211	9610
5	8658	11221	11500	11787	11946	12601	12765	12935	12986	13373	14110
6	10637	10966	12275	12075	11627	12517	13535	13573	13128	14156	14237
7	9555	11525	12382	12234	11514	11001	11275	12864	12804	12652	13741
8	14865	14006	14441	14803	15528	16525	16368	16176	16432	16491	16472
Mean	9404	10293	11307	11434	11507	11904	12109	12488	12738	12889	13067
SD	2430	2018	1728	1702	1827	2094	2175	1947	1824	2090	2054

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3750	3759	4149	3784	3588	4077	4401	4084	4405	4482	4771
2	3079	3169	3114	3041	3164	2970	3197	3230	3128	3163	3006
3	3949	5014	4068	3972	4166	4140	4275	3943	4012	4044	3922
4	2552	3146	3266	3150	3176	3241	3038	3005	3191	3264	3285
5	4074	4125	3801	4419	4108	4042	3936	4023	3994	3620	3534
6	3452	3639	3488	3905	3487	3829	3815	3894	3582	3583	3945
7	3532	3809	4175	4166	4003	4460	4026	4078	4029	4005	4489
8	3583	4074	3597	3701	3869	3823	3818	4047	3766	3810	3879
Mean	3496	3842	3707	3767	3695	3823	3813	3788	3763	3746	3854
SD	490	597	407	472	401	491	478	423	441	433	586

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.4825	0.4125	0.3767	0.3514	0.3448	0.3731	0.3881	0.3515	0.3627	0.3549	0.3831
2	0.3887	0.4070	0.3296	0.2985	0.2847	0.2629	0.2737	0.2681	0.2411	0.2407	0.2443
3	0.4854	0.5500	0.4056	0.3860	0.3926	0.3890	0.3925	0.3537	0.3529	0.3529	0.3378
4	0.3319	0.3654	0.3488	0.3377	0.3410	0.3333	0.3370	0.3149	0.3171	0.3544	0.3418
5	0.4706	0.3677	0.3305	0.3749	0.3439	0.3208	0.3084	0.3110	0.3076	0.2707	0.2505
6	0.3245	0.3319	0.2842	0.3234	0.2999	0.3059	0.2819	0.2869	0.2728	0.2531	0.2771
7	0.3697	0.3305	0.3372	0.3405	0.3477	0.4054	0.3571	0.3170	0.3146	0.3166	0.3267
8	0.2410	0.2909	0.2491	0.2500	0.2491	0.2313	0.2333	0.2502	0.2292	0.2311	0.2355
Mean	0.3868	0.3820	0.3327	0.3328	0.3255	0.3277	0.3215	0.3067	0.2998	0.2968	0.2996
SD	0.0881	0.0790	0.0491	0.0433	0.0449	0.0608	0.0571	0.0368	0.0486	0.0538	0.0548

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	47	50	62	62	63	63	63	63	65	66	65
2	62	64	69	73	76	78	78	80	81	82	80
3	52	56	62	64	65	65	66	67	68	68	70
4	68	67	67	68	67	67	67	70	69	68	69
5	58	68	68	69	71	77	76	78	81	84	87
6	72	72	76	76	76	78	79	79	79	82	81
7	72	71	74	73	68	67	70	75	75	75	76
8	94	85	88	88	91	93	91	91	92	92	91
Mean	65	67	71	72	72	73	74	75	76	77	77
SD	14	10	9	8	9	10	9	9	9	9	9

BENCH PRESS FREE WEIGHT 40%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	172	170	173	179	181	186	186	186	188	183	186
2	127	141	146	138	146	166	151	166	163	169	160
3	132	173	156	177	161	168	170	178	182	182	181
4	152	144	147	143	142	136	147	140	144	145	148
5	148	155	170	170	161	161	158	157	162	163	159
6	145	167	152	166	165	160	171	173	164	174	173
7	135	156	154	154	148	158	156	156	157	164	172
8	157	162	162	162	166	170	174	168	175	185	172
Mean	146	158	157	161	159	163	164	166	167	171	169
SD	15	12	10	15	13	14	13	14	14	13	13

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	83	87	89	93	94	99	99	98	100	96	97
2	63	76	81	80	80	92	84	92	92	94	91
3	61	77	102	91	82	89	93	98	100	103	101
4	87	82	79	78	77	74	76	77	80	82	82
5	83	90	92	92	89	86	86	87	90	91	89
6	78	86	84	92	93	90	93	95	89	94	98
7	73	87	86	94	95	88	90	99	101	91	96
8	86	95	97	97	99	104	106	95	103	108	103
Mean	77	85	89	90	88	90	91	93	94	95	95
SD	10	6	8	7	8	9	9	7	8	8	7

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	172	169	169	177	178	183	183	184	184	179	181
2	126	141	146	131	142	164	149	164	159	164	158
3	131	163	153	171	157	166	170	175	176	178	177
4	148	142	143	143	141	136	141	140	143	145	146
5	148	152	162	162	159	155	155	157	158	160	150
6	142	153	148	159	160	156	164	165	157	165	166
7	134	150	150	143	144	151	154	151	153	159	161
8	155	158	160	158	162	163	166	162	168	170	169
Mean	144	153	154	155	155	159	160	162	162	165	164
SD	15	10	9	15	13	14	13	14	13	11	12

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	81	85	87	92	94	97	97	98	98	94	96
2	63	74	80	76	77	92	83	92	91	92	89
3	60	74	96	83	81	87	92	97	98	97	99
4	85	82	78	77	76	74	75	77	80	80	81
5	82	86	91	90	87	85	86	87	88	89	84
6	76	85	84	89	90	88	91	93	87	92	94
7	72	83	82	85	88	83	86	89	93	88	89
8	85	93	94	93	97	100	100	94	101	101	100
Mean	76	83	87	86	86	88	89	91	92	92	91
SD	10	6	7	7	8	8	8	7	7	6	7

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	113	116	118	124	124	129	129	131	130	126	128
2	90	105	109	100	108	124	115	124	122	122	118
3	90	112	121	115	114	122	126	130	132	130	131
4	112	107	108	108	105	102	104	107	111	111	111
5	111	116	121	121	118	115	115	118	119	121	113
6	106	115	113	122	121	118	124	124	119	125	125
7	100	115	114	107	109	116	118	113	115	122	122
8	114	120	122	121	125	128	128	124	130	130	129
Mean	104	113	116	115	115	119	120	121	122	123	122
SD	10	5	5	9	8	9	8	8	8	6	8

BENCH PRESS FREE WEIGHT 40%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7294	8435	8820	9409	9669	9972	10190	10503	9931	9796	10088
2	7896	9069	10245	9524	10752	12701	11845	12604	12568	12704	12580
3	7334	9152	14621	9591	10142	11365	12071	12271	13074	12724	13006
4	10797	10149	10278	10193	10077	9778	10215	10352	10646	10751	10885
5	11422	12567	13005	12659	11951	11542	11465	12238	12430	12582	11291
6	10073	11106	11251	12360	12361	11909	12588	12406	12078	13026	12858
7	8366	11024	10542	9337	9549	10731	10972	10008	10217	11411	11258
8	12581	13569	14013	14443	14873	15584	15843	14840	15869	15499	15864
Mean	9470	10634	11597	10939	11172	11698	11899	11903	12101	12312	12229
SD	2022	1791	2052	1947	1815	1847	1808	1585	1922	1717	1795

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	4440	4145	3862	4077	4234	4296	3908	4438	4419	4401	4049
2	2924	3468	3484	3274	3203	3510	3202	3479	3382	3436	3245
3	3132	4211	4870	4272	3808	3991	3565	4149	4106	4105	3961
4	3546	3486	3366	3251	3185	3276	3185	3293	3351	3309	3351
5	3178	3389	3403	3708	3582	3615	3572	3488	3480	3755	3390
6	3353	3856	3578	3810	3624	3444	3840	3742	3790	3920	3687
7	3377	3820	4148	3959	3918	4139	4355	3989	3961	4288	4161
8	3560	3635	3743	3711	4145	3842	3853	3750	4046	4247	3804
Mean	3439	3751	3807	3758	3712	3764	3685	3791	3817	3933	3706
SD	458	311	503	360	391	360	390	383	385	404	346

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.6088	0.4913	0.4379	0.4333	0.4379	0.4308	0.3835	0.4225	0.4450	0.4493	0.4014
2	0.3704	0.3824	0.3401	0.3437	0.2980	0.2764	0.2703	0.2760	0.2691	0.2705	0.2579
3	0.4270	0.4601	0.3331	0.4455	0.3754	0.3512	0.2953	0.3381	0.3140	0.3226	0.3045
4	0.3284	0.3435	0.3275	0.3190	0.3161	0.3350	0.3118	0.3181	0.3148	0.3078	0.3078
5	0.2782	0.2697	0.2617	0.2929	0.2997	0.3132	0.3116	0.2850	0.2800	0.2984	0.3003
6	0.3328	0.3472	0.3180	0.3083	0.2932	0.2892	0.3050	0.3016	0.3138	0.3009	0.2867
7	0.4036	0.3465	0.3935	0.4240	0.4103	0.3857	0.3970	0.3986	0.3877	0.3758	0.3696
8	0.2830	0.2679	0.2671	0.2569	0.2787	0.2465	0.2432	0.2527	0.2550	0.2740	0.2398
Mean	0.3790	0.3636	0.3349	0.3529	0.3387	0.3285	0.3147	0.3241	0.3224	0.3249	0.3085
SD	0.1068	0.0801	0.0590	0.0718	0.0606	0.0604	0.0522	0.0597	0.0640	0.0600	0.0537

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	42	50	52	53	54	54	56	57	54	55	56
2	63	64	70	73	76	78	80	77	79	78	79
3	56	56	96	56	65	69	71	70	74	72	73
4	73	72	72	71	72	72	72	74	74	74	75
5	77	83	80	78	75	74	74	78	79	79	75
6	71	73	76	78	77	76	77	75	77	79	78
7	63	74	70	65	66	71	71	66	67	72	70
8	81	86	88	91	92	96	95	92	94	91	94
Mean	66	70	76	71	72	74	75	74	75	75	75
SD	13	12	13	12	11	11	11	10	11	10	11

BENCH PRESS EQUIPMENT 60%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	162	203	197	198	198	193	203	208	208	207	215
2	130	159	159	164	172	182	182	186	203	218	218
3	144	165	167	176	167	171	172	178	177	180	182
4	121	147	148	154	150	156	147	156	154	152	157
5	173	197	201	205	205	205	204	204	207	209	215
6	152	167	155	168	169	170	176	177	171	175	178
7	144	165	168	170	175	173	180	184	185	186	187
8	155	169	169	178	182	181	187	186	188	190	195
Mean	148	171	170	177	177	179	181	185	187	190	193
SD	17	19	19	17	18	15	18	16	19	21	21

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	74	115	115	112	112	116	119	120	120	122	131
2	64	88	85	92	103	111	109	106	136	143	143
3	72	92	105	99	90	91	95	98	100	102	102
4	65	79	77	81	78	81	79	80	82	82	85
5	115	127	131	136	135	135	134	134	137	137	142
6	85	96	90	96	95	101	100	102	101	102	98
7	81	97	104	101	103	105	104	111	111	113	111
8	89	100	103	109	110	108	113	110	109	112	116
Mean	81	99	101	103	103	106	107	108	112	114	116
SD	16	15	17	17	17	16	16	16	18	20	21

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	162	190	188	186	187	190	193	201	201	202	203
2	129	156	158	156	166	172	173	176	191	199	191
3	142	161	155	168	162	163	168	173	173	176	178
4	120	147	147	151	150	152	147	151	154	152	155
5	173	193	198	203	204	203	201	202	204	208	212
6	151	160	152	161	161	165	165	166	166	165	170
7	144	152	163	167	172	162	173	182	182	180	184
8	151	154	167	176	177	179	184	183	183	186	191
Mean	147	164	166	171	172	173	176	179	182	184	186
SD	17	17	18	17	17	17	17	17	17	19	18

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	74	100	104	103	105	109	111	117	117	115	118
2	63	82	83	85	98	104	101	103	116	119	120
3	72	85	96	87	88	89	92	96	97	99	100
4	63	79	77	80	78	79	78	78	80	81	83
5	113	124	130	134	133	133	132	132	134	137	140
6	85	92	87	92	93	96	95	96	96	96	96
7	77	89	98	95	102	98	103	108	110	111	110
8	88	93	102	108	106	106	110	106	106	109	113
Mean	79	93	97	98	100	102	103	105	107	108	110
SD	16	14	16	17	16	16	16	16	16	17	17

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	108	137	137	138	139	140	145	150	151	152	150
2	90	112	115	119	131	132	134	139	146	154	146
3	102	116	125	120	119	122	125	129	131	133	134
4	87	108	109	112	112	114	110	111	114	114	117
5	142	156	163	166	166	165	164	165	166	170	174
6	114	121	117	124	123	127	126	126	129	127	130
7	109	118	124	128	131	125	134	140	141	140	142
8	114	118	130	138	136	138	143	139	140	143	147
Mean	108	123	128	131	132	133	135	137	140	142	142
SD	17	16	17	17	16	15	16	16	16	18	17

BENCH PRESS EQUIPMENT 60%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7380	11214	11919	12290	12346	12836	13291	13835	13793	13731	14092
2	7366	9601	10238	11086	12420	13289	13513	14066	15460	16287	15888
3	8783	9835	15630	11019	11450	11771	12456	12998	13393	13643	13797
4	8075	9963	10334	10788	10814	10931	10613	10922	11326	11264	11625
5	12043	14267	16328	17682	17931	17766	17648	17952	18571	19230	19777
6	11145	11516	12005	13006	12970	13752	13687	13815	14438	13826	14542
7	9395	11366	12280	12949	13254	12667	14104	14689	15004	15075	15584
8	13059	13465	15884	17171	17345	17422	18510	17612	18086	18694	19443
Mean	9656	11403	13077	13249	13566	13804	14228	14486	15009	15219	15593
SD	2180	1702	2498	2721	2636	2498	2617	2323	2401	2715	2797

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3937	4870	4412	4573	4345	4505	4578	4276	4492	4322	4675
2	3007	3461	3680	3672	4028	4150	3970	4466	4462	4515	4139
3	3302	4305	3824	4712	3510	3510	3655	3829	4000	3820	4069
4	2782	3374	3413	3348	3225	3319	3163	3290	3224	3348	3449
5	4874	5932	4661	4841	4535	4562	4901	4613	4952	4679	4762
6	3428	3921	3434	3904	3585	3786	3744	3897	3669	3773	3504
7	3939	3728	3885	4176	4029	4432	4361	4254	4065	4062	4210
8	3492	4466	3978	4204	3712	4109	3644	3841	4094	3776	3959
Mean	3595	4257	3911	4179	3871	4047	4002	4058	4120	4037	4096
SD	655	848	440	521	442	467	572	427	531	444	475

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5334	0.4342	0.3702	0.3721	0.3520	0.3510	0.3444	0.3091	0.3257	0.3147	0.3318
2	0.4082	0.3605	0.3595	0.3312	0.3243	0.3123	0.2937	0.3175	0.2886	0.2772	0.2605
3	0.3759	0.4377	0.2447	0.4276	0.3065	0.2982	0.2935	0.2946	0.2987	0.2800	0.2949
4	0.3445	0.3387	0.3303	0.3103	0.2982	0.3036	0.2981	0.3012	0.2846	0.2972	0.2967
5	0.4047	0.4158	0.2854	0.2738	0.2529	0.2568	0.2777	0.2569	0.2667	0.2433	0.2408
6	0.3076	0.3405	0.2861	0.3002	0.2764	0.2753	0.2735	0.2821	0.2541	0.2729	0.2410
7	0.4192	0.3280	0.3164	0.3225	0.3040	0.3499	0.3092	0.2896	0.2709	0.2695	0.2701
8	0.2674	0.3317	0.2504	0.2448	0.2140	0.2359	0.1969	0.2181	0.2264	0.2020	0.2036
Mean	0.3826	0.3734	0.3054	0.3228	0.2910	0.2979	0.2859	0.2836	0.2770	0.2696	0.2674
SD	0.0807	0.0476	0.0468	0.0569	0.0429	0.0411	0.0421	0.0322	0.0299	0.0343	0.0402

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	45	59	64	66	66	68	69	69	69	68	69
2	57	62	65	71	75	77	78	80	81	82	83
3	62	61	101	65	71	72	74	75	77	78	77
4	67	68	70	71	72	72	72	72	74	74	75
5	70	74	82	87	88	87	88	89	91	92	93
6	74	72	79	81	81	84	83	83	87	84	86
7	65	75	75	77	77	78	81	81	83	84	85
8	87	87	95	97	98	97	101	96	99	100	102
Mean	66	70	79	77	78	79	81	81	82	83	84
SD	12	9	13	11	10	10	10	9	10	10	10

BENCH PRESS FREE WEIGHT 60%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	152	168	174	181	181	186	187	190	190	193	189
2	141	150	150	157	163	163	175	175	181	183	184
3	139	176	151	159	167	167	174	177	178	173	181
4	144	165	158	165	174	176	173	168	164	167	172
5	169	178	184	177	177	176	179	178	183	184	190
6	160	168	160	165	168	170	163	165	171	168	174
7	152	161	161	156	157	162	170	170	174	175	177
8	137	167	161	171	174	180	185	182	182	185	181
Mean	149	167	162	166	170	172	176	176	178	179	181
SD	11	9	11	9	8	8	8	8	8	9	6

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	76	95	99	102	104	109	110	114	114	111	110
2	72	81	81	92	92	93	102	104	106	109	108
3	69	81	79	84	93	93	97	100	97	97	105
4	73	94	87	87	94	95	91	92	91	91	94
5	103	105	105	105	101	100	103	103	108	108	112
6	87	99	92	94	97	98	92	95	97	94	97
7	87	104	100	97	100	111	97	102	103	105	105
8	81	100	102	106	111	114	111	114	114	111	109
Mean	81	95	93	96	99	101	100	103	104	103	105
SD	11	9	10	8	6	9	7	8	8	8	6

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	151	165	167	174	175	179	181	182	183	186	186
2	137	145	145	152	159	162	172	174	177	179	181
3	138	160	149	155	159	164	168	171	171	171	176
4	144	154	158	152	167	170	168	166	162	165	167
5	166	172	176	173	173	173	175	175	180	182	184
6	158	167	159	160	166	168	160	164	168	164	170
7	149	155	151	146	152	156	163	156	165	170	174
8	134	162	159	165	171	177	183	180	181	180	179
Mean	147	160	158	160	165	169	171	171	173	175	177
SD	11	8	10	10	8	8	8	9	8	8	7

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	74	93	94	100	103	104	107	108	107	108	106
2	70	78	77	86	91	92	100	101	105	107	106
3	68	79	78	83	87	91	95	95	93	93	100
4	73	86	87	83	92	93	90	90	88	89	92
5	103	103	104	102	101	99	103	102	106	107	110
6	87	98	91	92	96	97	91	94	95	92	96
7	83	94	91	90	92	96	93	95	99	99	104
8	78	99	100	104	107	110	109	108	109	108	106
Mean	79	91	90	93	96	98	98	99	100	100	103
SD	12	9	9	8	7	7	7	7	8	8	6

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	103	123	127	131	133	135	136	138	136	139	138
2	98	107	108	118	121	124	131	134	136	138	139
3	97	111	108	113	119	124	127	126	126	127	132
4	103	115	114	116	125	128	127	124	122	125	127
5	131	134	136	134	133	133	136	136	141	142	145
6	119	126	122	123	127	128	122	125	127	124	128
7	115	119	115	114	116	120	125	120	130	132	134
8	101	126	125	130	136	140	142	140	140	140	139
Mean	108	120	119	123	126	129	131	130	132	133	135
SD	12	9	10	8	7	7	7	7	7	7	6

BENCH PRESS FREE WEIGHT 60%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7111	10338	11150	11251	11599	12040	12453	12624	11966	12209	12453
2	7956	9640	9835	11107	11989	12431	13394	13783	14003	14306	14521
3	8479	9204	9565	10357	11302	11846	12048	12105	12170	12347	13151
4	10900	11859	12390	12464	13711	14111	14284	14011	13728	14085	14509
5	13372	14536	14786	14150	14139	14415	14882	15315	16319	16679	17144
6	11584	13132	12520	12870	13217	13288	12638	13313	13504	13307	14078
7	10425	10629	10087	10086	10195	10676	11703	10708	12944	12732	12863
8	12058	15097	15457	16283	17421	18059	18446	18629	18330	18243	18092
Mean	10236	11804	11974	12321	12947	13358	13731	13811	14121	14239	14601
SD	2188	2238	2240	2099	2239	2263	2196	2382	2169	2166	2024

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3900	4526	4227	4045	4236	4387	4191	4778	4227	4151	4243
2	3103	3439	3362	3332	3504	3429	3628	3629	3683	3924	3870
3	3209	3436	3304	3798	3353	3783	4101	3796	4158	3623	3881
4	3201	3521	3567	3405	3567	3613	3466	3435	3524	3542	3314
5	3917	3885	3821	3845	6337	3931	3823	4036	3874	4000	3857
6	3770	4027	3715	3770	3928	3903	3898	3839	3799	3921	3833
7	4501	4201	4040	4180	3890	4250	4266	4112	4383	4159	4052
8	3269	3669	4045	4090	3621	4243	3971	3794	3780	4728	3973
Mean	3609	3838	3760	3808	4055	3942	3918	3927	3928	4006	3878
SD	493	395	335	308	964	334	275	404	296	367	266

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5485	0.4378	0.3791	0.3595	0.3652	0.3644	0.3366	0.3785	0.3532	0.3400	0.3408
2	0.3901	0.3568	0.3418	0.3000	0.2922	0.2759	0.2708	0.2633	0.2630	0.2743	0.2665
3	0.3784	0.3733	0.3454	0.3667	0.2967	0.3193	0.3404	0.3136	0.3417	0.2934	0.2951
4	0.2937	0.2969	0.2879	0.2732	0.2602	0.2561	0.2426	0.2451	0.2567	0.2514	0.2284
5	0.2929	0.2673	0.2584	0.2717	0.4482	0.2727	0.2569	0.2635	0.2374	0.2398	0.2250
6	0.3254	0.3066	0.2967	0.2929	0.2972	0.2937	0.3085	0.2884	0.2813	0.2946	0.2723
7	0.4317	0.3953	0.4005	0.4144	0.3816	0.3981	0.3645	0.3840	0.3386	0.3266	0.3150
8	0.2711	0.2430	0.2617	0.2512	0.2079	0.2350	0.2153	0.2037	0.2062	0.2592	0.2196
Mean	0.3665	0.3346	0.3214	0.3162	0.3186	0.3019	0.2919	0.2925	0.2848	0.2849	0.2703
SD	0.0923	0.0670	0.0532	0.0572	0.0758	0.0556	0.0533	0.0633	0.0541	0.0356	0.0447

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	47	63	67	65	66	67	69	69	66	66	67
2	58	67	68	73	75	77	78	79	79	80	80
3	61	57	64	67	71	72	72	71	71	72	75
4	76	77	78	82	82	83	85	85	85	86	87
5	80	85	84	82	82	83	85	87	90	92	93
6	73	79	79	80	79	79	79	81	80	81	83
7	70	68	67	69	67	69	72	69	79	75	74
8	90	93	98	99	102	102	101	104	101	101	101
Mean	70	74	75	77	78	79	80	81	81	82	83
SD	14	12	11	11	11	11	10	12	11	11	11

OVERHEAD PRESS EQUIPMENT 40%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	161	179	179	180	180	183	181	189	192	195	199
2	133	141	141	151	150	155	170	162	159	170	170
3	147	169	168	166	165	168	169	171	173	173	176
4	138	139	142	149	159	166	169	166	177	179	179
5	130	163	163	166	157	155	157	157	159	164	175
6	144	166	165	170	178	180	188	189	193	196	197
7	138	153	145	165	176	171	172	168	178	179	181
8	146	173	176	176	180	185	182	187	189	192	188
Mean	142	160	160	165	168	170	174	174	177	181	183
SD	10	15	15	11	12	12	10	13	13	12	11

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	69	100	103	100	98	104	110	107	116	115	121
2	63	69	71	77	80	93	97	85	94	95	93
3	65	85	87	91	91	96	93	96	98	100	102
4	62	71	70	72	78	83	88	87	92	92	92
5	60	88	89	83	84	86	86	89	88	91	97
6	72	87	88	94	96	98	102	103	103	106	109
7	75	93	91	96	100	96	100	98	108	109	110
8	85	102	104	107	107	109	109	109	111	111	110
Mean	69	87	88	90	92	96	98	97	101	102	104
SD	8	12	13	12	10	9	9	9	10	9	10

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	161	176	177	176	176	179	178	182	186	190	193
2	131	137	139	148	148	154	160	156	155	160	159
3	146	165	166	165	164	166	167	168	170	171	175
4	136	137	142	147	155	164	167	166	170	174	179
5	127	151	160	164	156	153	154	155	156	161	171
6	143	162	161	166	173	174	177	182	183	187	189
7	135	152	137	161	160	165	158	166	174	174	175
8	146	166	172	173	175	178	179	185	185	184	186
Mean	141	156	157	162	163	167	168	170	172	175	178
SD	11	14	15	10	11	10	10	12	12	11	11

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	69	94	92	94	93	96	95	99	107	107	109
2	60	66	68	77	78	87	86	83	86	90	90
3	64	85	84	82	87	92	90	94	96	95	97
4	60	68	70	71	76	80	85	87	87	89	92
5	58	80	88	81	80	83	76	85	85	89	97
6	69	84	84	91	93	94	97	98	98	100	101
7	69	88	79	92	94	95	94	96	101	102	105
8	84	98	102	104	105	106	107	108	109	107	107
Mean	67	83	83	86	88	92	91	94	96	97	100
SD	8	12	11	11	10	8	9	8	9	8	7

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	106	129	127	126	127	130	130	134	138	142	144
2	90	96	102	109	111	117	116	117	119	122	118
3	95	117	115	116	118	122	123	125	126	127	130
4	91	98	104	107	112	118	120	123	124	126	134
5	87	105	119	116	113	114	116	116	118	122	130
6	102	118	119	124	128	130	132	135	136	140	142
7	99	116	123	123	120	125	119	126	132	133	134
8	107	127	132	132	136	137	137	141	142	140	139
Mean	97	113	118	119	120	124	124	127	129	131	134
SD	8	12	11	9	9	8	8	9	9	8	8

OVERHEAD PRESS EQUIPMENT 40%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7196	10780	10920	10984	11214	11756	11712	12553	12438	13405	13847
2	8822	9667	10613	11592	11982	13834	12845	12866	13229	13966	13442
3	7095	9367	9776	10397	10836	11764	11822	12112	12433	12821	13359
4	8944	9108	9608	10309	11121	11902	12704	12715	12853	13559	14436
5	7242	11529	13086	11877	11948	12980	13802	13858	14645	15365	17025
6	10865	12969	13733	14586	15361	15542	16531	16732	16985	17624	18158
7	9284	10206	10049	13032	12051	12718	12082	13296	14242	14540	14835
8	12433	15271	16335	17053	17706	18421	18384	19561	19436	19237	19314
Mean	8985	11112	11765	12479	12777	13614	13735	14212	14533	15065	15552
SD	1903	2104	2393	2333	2443	2326	2443	2595	2492	2255	2300

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3716	4940	4106	3728	3770	3804	4192	4557	3913	4608	4549
2	2716	2817	2841	3387	3192	2992	2945	3052	3563	2853	3385
3	3517	4373	4598	3682	3975	4119	3945	3927	4268	4086	4194
4	2866	3245	3213	3507	3363	3401	3315	3472	3650	3765	3646
5	3336	3292	3810	3780	3033	3581	3096	3131	3062	3230	3331
6	3075	3569	3371	3426	3580	3775	3865	3591	3697	3787	3847
7	3088	3649	3474	3485	3903	3905	3829	3686	4538	3880	4486
8	3170	3973	3846	3620	3595	4012	3853	3674	3690	3747	3805
Mean	3186	3732	3657	3577	3552	3699	3630	3636	3798	3744	3905
SD	329	679	551	146	335	366	449	472	451	527	465

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5164	0.4582	0.3760	0.3394	0.3362	0.3236	0.3579	0.3630	0.3146	0.3437	0.3285
2	0.3079	0.2914	0.2677	0.2922	0.2664	0.2163	0.2293	0.2372	0.2693	0.2043	0.2518
3	0.4957	0.4668	0.4703	0.3542	0.3668	0.3501	0.3337	0.3242	0.3433	0.3187	0.3139
4	0.3205	0.3563	0.3344	0.3402	0.3024	0.2857	0.2609	0.2731	0.2840	0.2776	0.2526
5	0.4606	0.2856	0.2912	0.3183	0.2539	0.2759	0.2243	0.2259	0.2091	0.2102	0.1957
6	0.2830	0.2752	0.2455	0.2349	0.2331	0.2429	0.2338	0.2146	0.2177	0.2149	0.2119
7	0.3326	0.3575	0.3457	0.2674	0.3239	0.3070	0.3169	0.2772	0.3187	0.2669	0.3024
8	0.2550	0.2602	0.2354	0.2123	0.2030	0.2178	0.2096	0.1878	0.1898	0.1948	0.1970
Mean	0.3715	0.3439	0.3208	0.2948	0.2857	0.2774	0.2708	0.2629	0.2683	0.2539	0.2567
SD	0.1028	0.0814	0.0782	0.0525	0.0559	0.0491	0.0570	0.0587	0.0570	0.0566	0.0533

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	45	61	62	63	64	66	66	69	67	71	72
2	67	71	76	78	81	90	80	82	85	87	85
3	49	57	59	63	66	71	71	72	73	75	76
4	66	67	68	70	72	73	76	77	76	78	81
5	57	77	82	73	77	85	90	90	94	95	99
6	76	80	85	88	89	89	93	92	93	94	96
7	69	67	73	81	75	77	76	80	82	83	85
8	85	92	95	99	101	104	103	106	105	104	104
Mean	64	71	75	77	78	82	82	84	84	86	87
SD	14	11	12	12	12	12	12	12	12	11	11

OVERHEAD PRESS FREE WEIGHT 40%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	151	175	177	177	182	182	176	177	179	195	195
2	144	164	165	162	160	160	161	168	168	169	169
3	161	174	175	178	177	179	179	180	185	182	185
4	125	150	165	157	142	151	155	166	167	166	145
5	150	143	147	149	152	150	155	163	163	167	167
6	145	155	161	167	170	171	174	182	183	184	187
7	129	142	154	159	156	162	165	166	169	169	176
8	147	166	171	171	179	185	185	189	197	193	203
Mean	144	159	164	165	165	168	169	174	176	178	178
SD	12	13	10	10	14	13	11	9	12	12	18

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	69	99	99	100	109	109	103	108	104	115	115
2	68	92	92	87	88	86	87	95	89	96	96
3	76	91	93	92	103	96	99	99	104	110	112
4	60	78	84	82	74	76	79	85	88	91	82
5	79	86	82	80	80	79	85	89	89	92	92
6	79	86	87	93	94	95	97	98	100	98	97
7	71	84	93	97	92	99	103	99	105	101	105
8	85	98	99	98	104	107	109	108	110	109	119
Mean	73	89	91	91	93	93	95	98	98	102	102
SD	8	7	6	7	12	12	10	8	8	9	13

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	151	160	168	168	169	174	172	171	173	183	185
2	142	164	160	160	156	157	160	163	163	164	164
3	161	172	173	176	176	176	176	178	182	181	182
4	121	147	157	157	137	151	155	165	165	161	142
5	148	138	146	146	148	147	149	157	157	159	162
6	144	152	156	163	164	167	170	174	179	178	183
7	125	141	154	141	151	160	149	162	149	165	173
8	145	162	164	165	171	178	181	183	184	184	188
Mean	142	155	160	159	159	164	164	169	169	172	172
SD	13	12	8	11	13	12	12	9	13	10	15

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	67	91	94	95	97	101	95	95	97	104	107
2	66	87	86	84	86	84	86	89	89	92	92
3	75	87	88	90	99	94	97	96	101	106	106
4	59	77	79	82	74	76	79	84	87	88	80
5	78	76	80	78	79	78	81	87	87	89	91
6	78	83	85	90	93	94	93	97	97	96	97
7	70	84	87	96	87	97	93	97	104	98	103
8	82	96	96	97	103	106	106	107	107	107	110
Mean	72	85	87	89	90	91	91	94	96	98	98
SD	8	7	6	7	10	11	9	7	8	7	10

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	96	119	124	126	127	130	127	127	130	137	137
2	98	119	115	119	116	117	120	121	123	123	121
3	109	120	123	128	129	129	128	132	136	136	136
4	82	106	114	114	100	110	115	121	124	118	106
5	107	102	109	109	108	108	111	118	118	121	122
6	108	114	117	122	125	126	127	131	133	132	136
7	94	111	120	112	117	126	114	125	122	127	133
8	108	124	125	127	133	138	138	140	140	141	144
Mean	100	114	118	119	119	123	123	127	128	129	129
SD	10	7	5	7	11	10	9	7	8	9	12

OVERHEAD PRESS FREE WEIGHT 40%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	6348	9865	11339	11827	12250	12590	12543	12238	12591	13394	13490
2	8722	10402	10640	11501	11581	11947	12233	12779	13407	13299	12849
3	9671	10524	11244	12135	12350	12775	12869	13365	14020	13945	14311
4	7975	10410	11637	11486	10344	11686	12350	13070	13156	12872	11709
5	11295	11086	12170	12126	11894	11858	12421	13615	13858	14571	15097
6	11055	12698	13379	14306	14554	14977	15347	15985	16371	16358	17022
7	7828	10972	13509	10832	11542	12186	11544	12994	13998	13536	14031
8	12869	15517	16055	16527	17686	18877	19214	19662	19451	19785	20591
Mean	9470	11434	12497	12592	12775	13362	13565	14213	14607	14720	14888
SD	2160	1852	1759	1888	2311	2462	2543	2469	2251	2316	2788

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3747	3681	3875	3908	3907	3795	3746	3690	3737	3698	4015
2	3070	3566	3681	3746	3516	3400	3493	3185	3572	3425	3311
3	3630	4170	4210	4086	3810	4005	3843	3965	4027	4097	3960
4	2929	3567	3389	3696	3403	3281	3328	3491	3518	3786	3586
5	3240	3496	2900	3134	3200	3130	3465	3241	3366	3307	3142
6	3148	3323	3258	3623	3456	3771	3428	3738	3696	3793	3717
7	3811	4144	4314	3484	4062	4289	3919	4013	4466	4139	4231
8	3664	3976	3722	3726	3685	3739	3456	3635	3651	3629	4249
Mean	3405	3740	3669	3675	3630	3676	3585	3620	3754	3734	3776
SD	345	317	477	284	287	386	219	303	345	291	410

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5903	0.3731	0.3417	0.3304	0.3190	0.3014	0.2986	0.3015	0.2968	0.2761	0.2976
2	0.3520	0.3428	0.3459	0.3257	0.3036	0.2846	0.2856	0.2493	0.2664	0.2576	0.2577
3	0.3753	0.3962	0.3744	0.3367	0.3085	0.3135	0.2986	0.2967	0.2872	0.2938	0.2767
4	0.3673	0.3426	0.2913	0.3218	0.3290	0.2808	0.2695	0.2671	0.2674	0.2942	0.3062
5	0.2868	0.3153	0.2383	0.2584	0.2691	0.2640	0.2790	0.2380	0.2429	0.2269	0.2081
6	0.2848	0.2617	0.2435	0.2533	0.2374	0.2518	0.2233	0.2338	0.2258	0.2319	0.2183
7	0.4869	0.3777	0.3194	0.3217	0.3519	0.3520	0.3395	0.3089	0.3190	0.3057	0.3015
8	0.2847	0.2562	0.2318	0.2254	0.2084	0.1981	0.1799	0.1849	0.1877	0.1834	0.2063
Mean	0.3785	0.3332	0.2983	0.2967	0.2909	0.2808	0.2717	0.2600	0.2617	0.2587	0.2591
SD	0.1092	0.0522	0.0554	0.0435	0.0487	0.0456	0.0494	0.0421	0.0420	0.0421	0.0429

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	42	62	68	70	73	72	73	71	73	73	73
2	61	63	67	72	74	76	76	79	82	81	78
3	60	61	65	69	70	72	73	75	77	77	79
4	66	71	74	73	76	77	80	79	80	80	82
5	76	80	83	83	81	80	83	87	88	91	93
6	77	84	86	88	89	90	90	92	91	92	93
7	63	78	88	77	76	76	78	80	94	82	81
8	88	96	98	100	104	106	106	107	106	108	109
Mean	67	74	79	79	80	81	82	84	86	86	86
SD	14	12	12	11	11	11	11	11	11	11	12

OVERHEAD PRESS EQUIPMENT 60%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	164	244	182	190	190	186	191	235	199	198	193
2	138	157	152	155	158	162	169	169	173	177	177
3	144	164	170	169	169	168	169	174	177	178	181
4	126	141	146	131	146	153	156	184	187	191	190
5	165	176	200	209	206	202	200	207	220	225	230
6	141	164	176	182	184	185	195	196	203	204	207
7	134	154	149	165	166	162	175	176	176	178	194
8	165	185	176	181	184	187	192	195	198	199	206
Mean	147	173	169	173	175	176	181	192	192	194	197
SD	16	32	19	24	19	17	16	22	16	17	17

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	76	114	106	110	110	104	149	114	126	109	110
2	61	73	72	77	86	87	93	91	102	104	100
3	63	90	98	93	98	93	102	104	107	111	114
4	68	81	78	82	79	96	99	107	114	116	113
5	98	109	122	132	132	129	129	135	137	143	150
6	77	102	110	107	110	118	114	116	116	117	121
7	68	111	89	102	102	109	109	113	108	110	120
8	84	103	100	104	109	111	113	116	121	120	124
Mean	74	98	97	101	103	106	113	112	116	116	119
SD	12	15	17	17	16	14	18	13	11	12	15

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	163	200	176	179	185	183	185	196	185	188	191
2	135	146	147	151	154	159	161	161	164	168	167
3	144	162	164	166	167	166	167	170	172	174	176
4	126	139	143	118	146	153	154	177	184	185	178
5	165	170	194	206	200	199	198	201	209	215	225
6	140	157	169	173	177	179	186	190	193	196	198
7	134	137	145	158	162	160	169	173	173	176	192
8	162	178	172	176	180	184	186	191	194	196	199
Mean	146	161	164	166	171	173	176	182	185	187	191
SD	15	21	18	25	18	16	15	14	15	15	18

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	74	104	96	95	104	99	113	108	106	103	105
2	60	69	71	74	81	84	87	87	92	94	95
3	62	88	88	91	90	88	97	101	101	105	110
4	68	77	75	73	79	96	91	101	105	108	101
5	98	103	120	125	124	123	123	127	133	137	145
6	77	90	98	97	102	104	108	108	108	108	109
7	68	92	86	95	100	101	102	103	96	101	113
8	82	101	96	102	107	108	110	113	117	116	120
Mean	74	91	91	94	98	100	104	106	107	109	112
SD	12	12	15	16	15	12	12	11	13	13	15

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	106	-	124	129	133	136	140	139	-	-	136
2	91	104	105	109	113	117	119	122	125	129	127
3	93	115	120	120	123	122	128	131	134	137	138
4	92	104	105	91	113	120	119	135	141	141	135
5	130	136	155	161	158	157	156	161	168	173	181
6	104	120	127	132	135	135	143	146	148	150	150
7	92	106	112	123	126	127	130	135	130	133	152
8	114	133	128	133	139	142	143	148	151	152	156
Mean	103	117	122	125	130	132	135	139	142	145	147
SD	14	13	16	20	15	13	13	12	15	15	17

OVERHEAD PRESS EQUIPMENT 60%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7198	12105	10964	11388	11934	13409	12576	12880	12399	11958	13019
2	8549	9557	10187	10817	11353	11929	12618	12710	13523	14253	14169
3	6975	9636	11311	11423	12063	12331	13169	13724	14003	14848	14877
4	8215	9886	10602	8996	11631	12222	13287	15338	16437	16994	16625
5	12177	13592	18185	19018	18860	19237	19224	20472	21818	23706	25317
6	10358	12728	15095	15811	16361	16947	18158	19026	19520	20115	20637
7	7071	9983	12070	12854	13592	14189	14335	16054	14999	13056	18365
8	12360	15180	15896	17080	18352	19464	19777	20794	21383	21746	22441
Mean	9113	11583	13039	13423	14268	14966	15393	16375	16760	17084	18181
SD	2237	2134	2956	3489	3125	3142	3109	3321	3682	4314	4330

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	4117	4288	3739	3887	4406	5004	4159	4088	4146	3661	3729
2	2793	2798	2893	3179	3128	3110	2982	3474	3198	3868	3424
3	3308	3984	4247	3624	4183	3801	3981	4141	4032	3810	4458
4	3326	3445	3290	3557	3474	3973	3610	3762	4294	3560	4089
5	3133	3471	3264	3765	3752	3770	4047	3791	3970	3990	3801
6	3635	4798	3937	4204	4319	3919	4082	3872	4052	4107	3514
7	3374	4020	3470	4222	3828	4004	3883	3717	3597	3226	3974
8	2678	4580	3845	4050	3950	3956	4124	3763	3692	4044	3998
Mean	3296	3923	3586	3811	3880	3942	3858	3826	3873	3783	3873
SD	456	659	437	356	434	518	395	212	355	293	332

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5720	0.3542	0.3411	0.3413	0.3692	0.3732	0.3307	0.3174	0.3344	0.3062	0.2864
2	0.3267	0.2927	0.2839	0.2939	0.2755	0.2607	0.2363	0.2733	0.2365	0.2714	0.2417
3	0.4744	0.4134	0.3755	0.3172	0.3468	0.3083	0.3023	0.3018	0.2880	0.2566	0.2996
4	0.4049	0.3485	0.3104	0.3954	0.2987	0.3251	0.2717	0.2452	0.2612	0.2095	0.2459
5	0.2573	0.2554	0.1795	0.1980	0.1989	0.1960	0.2105	0.1852	0.1820	0.1683	0.1501
6	0.3509	0.3770	0.2608	0.2659	0.2640	0.2312	0.2248	0.2035	0.2076	0.2042	0.1703
7	0.4772	0.4027	0.2875	0.3285	0.2817	0.2822	0.2709	0.2315	0.2398	0.2471	0.2164
8	0.2167	0.3017	0.2419	0.2371	0.2153	0.2033	0.2085	0.1810	0.1726	0.1860	0.1781
Mean	0.3850	0.3432	0.2851	0.2972	0.2813	0.2725	0.2570	0.2424	0.2403	0.2311	0.2236
SD	0.1201	0.0557	0.0604	0.0626	0.0583	0.0618	0.0445	0.0518	0.0543	0.0468	0.0547

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	44	61	62	64	65	73	68	66	67	64	68
2	63	66	69	71	74	75	79	79	82	85	85
3	49	59	69	69	72	74	79	81	81	85	85
4	65	71	74	76	80	80	87	87	89	92	94
5	74	80	94	92	94	97	97	102	104	110	113
6	74	81	90	91	92	95	98	100	101	103	104
7	53	73	83	81	84	89	85	93	86	74	95
8	76	85	92	97	102	106	106	109	110	111	113
Mean	62	72	79	80	83	86	87	89	90	90	95
SD	12	10	12	12	13	12	13	14	14	17	15

OVERHEAD PRESS FREE WEIGHT 60%

PSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	168	200	186	187	189	194	198	199	197	201	209
2	149	187	175	162	128	167	163	178	178	178	168
3	173	187	180	179	182	178	181	182	185	189	190
4	122	144	139	143	159	161	161	172	177	188	179
5	180	184	182	188	192	190	189	195	198	206	211
6	151	165	168	171	179	186	189	193	199	202	203
7	145	175	170	170	170	171	175	184	187	187	184
8	155	173	177	186	192	197	200	205	209	209	209
Mean	155	177	172	173	174	181	182	189	191	195	194
SD	18	17	15	15	22	13	15	11	11	11	16

PDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	75	116	106	106	109	113	119	122	122	121	131
2	75	109	109	90	75	85	97	98	98	98	94
3	89	109	105	105	108	102	102	107	114	121	124
4	59	87	80	79	87	89	92	95	100	103	98
5	111	102	104	112	114	112	114	120	126	127	131
6	79	91	95	94	100	103	106	107	111	117	116
7	78	98	100	99	100	102	104	110	112	113	113
8	81	104	109	110	113	122	123	125	127	130	128
Mean	81	102	101	99	101	103	107	110	114	116	117
SD	15	10	10	11	14	12	11	11	11	11	14

XSBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	165	187	179	179	183	186	190	191	190	193	196
2	146	174	169	157	127	155	156	165	166	170	163
3	173	183	178	177	181	175	176	180	184	188	188
4	122	143	139	137	155	161	159	168	177	184	171
5	179	181	181	185	190	186	187	192	197	203	210
6	149	163	165	169	176	182	187	188	195	199	201
7	140	166	168	169	168	166	172	181	180	185	182
8	151	172	175	181	187	192	196	201	207	205	205
Mean	153	171	169	169	171	175	178	183	187	191	190
SD	19	14	13	16	21	13	15	12	13	12	17

XDBP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	75	104	98	100	102	106	109	112	111	113	117
2	71	102	99	87	71	82	92	96	95	97	93
3	88	102	102	103	107	100	100	105	112	115	114
4	59	83	80	79	87	89	80	93	100	102	95
5	110	100	103	109	112	110	111	117	122	124	129
6	79	89	93	93	98	102	104	105	108	111	112
7	75	90	98	98	99	97	101	108	108	111	112
8	80	101	106	107	111	118	119	122	126	124	124
Mean	80	96	97	97	98	101	102	107	110	112	112
SD	15	8	8	10	14	11	12	10	10	9	13

MAP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	106	136	131	133	135	139	143	146	145	148	150
2	103	131	126	119	96	110	120	126	129	130	123
3	122	137	136	137	140	133	136	139	143	149	147
4	85	111	108	107	117	124	120	129	135	142	130
5	141	135	139	144	147	145	146	152	156	161	167
6	109	122	124	126	133	137	141	143	148	151	153
7	105	128	127	127	127	126	132	139	139	143	142
8	108	132	135	139	146	146	155	159	163	161	161
Mean	110	129	128	129	130	132	137	142	145	148	147
SD	16	9	10	12	17	12	12	11	11	10	15

OVERHEAD PRESS FREE WEIGHT 60%

RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	7287	11232	11592	12165	12341	12637	13453	13783	13896	14407	14568
2	9740	13099	13216	12535	10798	11963	14271	14237	14928	15506	14971
3	11435	13352	13433	14130	14655	14595	14712	15203	15828	16263	16592
4	8893	11006	10984	11043	12823	13975	13678	15137	16190	17092	15997
5	16137	14334	15743	17091	17724	17678	17872	19233	20322	21106	22495
6	11045	12906	13807	14524	15664	16675	17484	18362	19298	20193	20893
7	9763	12588	13424	13374	12966	12941	14246	15416	15645	16455	16413
8	12191	16629	17398	18097	19835	20165	21685	22403	23674	23456	23711
Mean	10811	13143	13700	14120	14601	15079	15925	16722	17473	18060	18205
SD	2647	1781	2072	2425	3016	2850	2868	2991	3314	3152	3592

DPTI

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	3726	4611	4009	4026	3979	4128	4246	4399	3988	4168	4144
2	3212	4032	3591	3514	3143	2415	2932	2847	3112	3520	3193
3	3761	5131	4194	4118	4353	4006	3989	3720	4041	4297	4517
4	2817	3479	3556	3551	3345	3545	3109	3238	3462	3729	3592
5	4019	4811	4270	3733	6247	4139	3987	3711	3757	3994	4111
6	3547	3864	3734	3656	3758	3731	3840	3667	3666	3664	3707
7	3825	3651	4120	4231	4404	4014	4390	4321	4333	4344	4377
8	3560	4101	3594	3535	3833	4236	3966	3943	3875	3817	4105
Mean	3558	4210	3883	3796	4133	3777	3807	3731	3779	3942	3968
SD	382	583	297	287	960	596	518	517	375	307	439

DPTI/RPP

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	0.5113	0.4106	0.3459	0.3310	0.3224	0.3267	0.3156	0.3192	0.2870	0.2893	0.2844
2	0.3298	0.3078	0.2717	0.2803	0.2910	0.2019	0.2055	0.2000	0.2084	0.2270	0.2133
3	0.3289	0.3843	0.3122	0.2915	0.2970	0.2745	0.2711	0.2447	0.2553	0.2642	0.2722
4	0.3168	0.3161	0.3237	0.3216	0.2608	0.2537	0.2273	0.2139	0.2139	0.2182	0.2246
5	0.2490	0.3356	0.2712	0.2184	0.3524	0.2341	0.2231	0.1930	0.1849	0.1892	0.1827
6	0.3212	0.2994	0.2705	0.2517	0.2399	0.2238	0.2196	0.1997	0.1900	0.1814	0.1774
7	0.3918	0.2901	0.3069	0.3164	0.3397	0.3102	0.3081	0.2803	0.2769	0.2640	0.2667
8	0.2920	0.2466	0.2065	0.1953	0.1932	0.2101	0.1829	0.1760	0.1637	0.1627	0.1731
Mean	0.3426	0.3238	0.2886	0.2758	0.2871	0.2544	0.2441	0.2283	0.2225	0.2245	0.2243
SD	0.0790	0.0525	0.0432	0.0499	0.0536	0.0460	0.0486	0.0493	0.0454	0.0452	0.0453

HR

SUBJECT	PRE	REP1	REP2	REP3	REP4	REP5	REP6	REP7	REP8	REP9	REP10
1	44	60	65	68	67	68	71	72	73	75	74
2	67	75	78	80	85	77	91	86	90	91	92
3	66	73	75	80	81	83	83	85	86	87	88
4	73	77	79	81	83	87	86	90	91	93	94
5	90	79	87	92	93	95	96	100	103	104	107
6	74	79	84	86	89	92	94	98	99	102	104
7	70	76	80	79	77	78	83	85	87	89	90
8	81	97	100	100	106	105	110	111	114	114	115
Mean	71	77	81	83	85	86	89	91	93	94	96
SD	13	10	10	10	11	12	12	12	12	12	13

APPENDIX C

ANALYSIS OF VARIANCE SUMMARY TABLES

MEAN SYSTOLIC BLOOD PRESSURE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	3733.1	7	659.9	5.66	0.049
2	1	876.4	7	729.9	1.20	0.309
3	1	19513.5	7	2253.2	8.66	0.022
4	10	5779.5	70	57.8	99.95	0.000
12	1	1377.3	7	431.4	3.19	0.117
13	1	63.7	7	606.8	0.10	0.755
23	1	52.2	7	349.9	0.15	0.711
14	10	129.6	70	101.8	1.27	0.262
24	10	79.4	70	41.6	1.91	0.058
34	10	163.9	70	28.8	5.69	0.000
123	1	847.4	7	92.9	9.12	0.019
124	10	26.5	70	40.7	0.65	0.765
134	10	22.1	70	30.8	0.72	0.705
234	10	11.2	70	28.5	0.39	0.946
1234	10	11.3	70	19.4	0.58	0.824

PEAK SYSTOLIC BLOOD PRESSURE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	4284.1	7	557.5	7.69	0.028
2	1	1248.4	7	739.7	1.69	0.235
3	1	22288.8	7	2205.1	10.11	0.016
4	10	6847.6	70	77.5	88.33	0.000
12	1	1241.3	7	534.9	2.32	0.171
13	1	28.8	7	648.6	0.04	0.839
23	1	28.9	7	402.1	0.07	0.796
14	10	165.5	70	120.7	1.37	0.212
24	10	84.8	70	63.3	1.34	0.227
34	10	172.6	70	40.6	4.25	0.000
123	1	561.9	7	51.4	10.92	0.013
124	10	17.8	70	42.1	0.42	0.931
134	10	46.8	70	47.5	0.99	0.464
234	10	30.5	70	40.9	0.75	0.679
1234	10	17.5	70	28.7	0.61	0.801

MEAN DIASTOLIC BLOOD PRESSURE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	589.1	7	370.7	1.59	0.248
2	1	97.3	7	538.4	0.18	0.684
3	1	18079.8	7	1647.3	10.98	0.013
4	10	3882.5	70	40.0	97.14	0.000
12	1	1153.2	7	300.2	3.84	0.091
13	1	25.2	7	234.2	0.11	0.752
23	1	54.0	7	182.6	0.30	0.603
14	10	134.7	70	40.9	3.29	0.002
24	10	46.4	70	25.7	1.81	0.075
34	10	79.5	70	14.6	5.46	0.000
123	1	229.3	7	39.6	5.80	0.047
124	10	14.3	70	20.5	0.70	0.724
134	10	12.1	70	17.0	0.71	0.709
234	10	4.6	70	13.4	0.34	0.966
1234	10	7.8	70	10.3	0.76	0.664

PEAK DIASTOLIC BLOOD PRESSURE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	1634.2	7	404.7	4.04	0.084
2	1	752.4	7	557.2	1.35	0.283
3	1	22498.5	7	1543.9	14.57	0.007
4	10	4621.8	70	61.2	75.55	0.000
12	1	710.9	7	407.4	1.75	0.228
13	1	28.2	7	322.1	0.09	0.776
23	1	304.0	7	209.1	1.45	0.267
14	10	183.7	70	53.5	3.44	0.001
24	10	79.6	70	48.4	1.64	0.112
34	10	112.9	70	22.3	5.05	0.000
123	1	167.8	7	87.7	1.91	0.209
124	10	29.0	70	28.0	1.04	0.422
134	10	14.2	70	24.6	0.58	0.825
234	10	13.3	70	24.1	0.55	0.847
1234	10	9.7	70	17.3	0.56	0.843

MEAN ARTERIAL PRESSURE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	1285.2	7	523.4	2.46	0.161
2	1	184.0	7	613.3	0.30	0.601
3	1	18924.2	7	2066.5	9.16	0.019
4	10	5054.2	70	37.7	134.13	0.000
12	1	1723.5	7	389.4	4.43	0.073
13	1	1.4	7	352.6	0.00	0.952
23	1	50.6	7	255.3	0.20	0.670
14	10	167.2	70	60.9	2.74	0.007
24	10	66.1	70	25.5	2.59	0.010
34	10	132.2	70	24.6	5.37	0.000
123	1	816.3	7	84.7	9.64	0.017
124	10	30.3	70	31.9	0.95	0.495
134	10	15.0	70	25.4	0.59	0.817
234	10	15.1	70	23.6	0.64	0.774
1234	10	22.7	70	13.5	1.69	0.101

RATE-PRESSURE PRODUCT

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	4.26E+08	7	1.58E+07	27.01	0.001
2	1	1.75E+05	7	1.24E+07	0.01	0.909
3	1	5.45E+08	7	3.73E+07	14.59	0.007
4	10	1.80E+08	70	1.31E+06	137.57	0.000
12	1	2.71E+07	7	8.52E+06	3.19	0.117
13	1	6.79E+05	7	5.51E+06	0.12	0.736
23	1	1.76E+06	7	3.66E+06	0.48	0.511
14	10	1.26E+07	70	1.59E+06	7.94	0.000
24	10	2.49E+06	70	8.01E+05	3.11	0.002
34	10	6.51E+06	70	5.82E+05	11.19	0.000
123	1	9.68E+06	7	2.50E+06	3.88	0.090
124	10	3.56E+05	70	4.98E+05	0.71	0.708
134	10	4.23E+05	70	4.65E+05	0.91	0.529
234	10	6.61E+05	70	4.94E+05	1.34	0.228
1234	10	1.36E+05	70	3.63E+05	0.38	0.953

DIASTOLIC PRESSURE TIME INDEX

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	1.99E+06	7	1.01E+06	1.98	0.203
2	1	2.79E+04	7	2.77E+05	0.10	0.760
3	1	6.17E+06	7	1.28E+06	4.84	0.064
4	10	9.88E+05	70	1.11E+05	8.89	0.000
12	1	6.71E+05	7	7.99E+05	0.84	0.390
13	1	2.54E+04	7	4.22E+05	0.06	0.813
23	1	3.12E+04	7	2.61E+05	0.12	0.740
14	10	6.27E+04	70	4.56E+04	1.38	0.209
24	10	1.25E+05	70	8.23E+04	1.52	0.151
34	10	8.84E+04	70	1.01E+05	0.88	0.560
123	1	4.22E+05	7	2.92E+05	1.44	0.268
124	10	7.38E+04	70	7.82E+04	0.94	0.500
134	10	3.39E+04	70	5.58E+04	0.61	0.803
234	10	5.23E+04	70	1.05E+05	0.50	0.885
1234	10	5.87E+04	70	4.72E+04	1.24	0.280

DIASTOLIC PRESSURE TIME INDEX TO RATE-PRESSURE PRODUCT RATIO
1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	0.2546	7	0.0043	59.32	0.000
2	1	0.0002	7	0.0100	0.02	0.880
3	1	0.0883	7	0.0049	18.16	0.004
4	10	0.0788	70	0.0027	29.58	0.000
12	1	0.0065	7	0.0065	1.00	0.352
13	1	0.0018	7	0.0024	0.76	0.412
23	1	0.0029	7	0.0050	0.58	0.470
14	10	0.0028	70	0.0008	3.44	0.001
24	10	0.0016	70	0.0009	1.68	0.102
34	10	0.0011	70	0.0007	1.49	0.162
123	1	0.0005	7	0.0019	0.25	0.636
124	10	0.0005	70	0.0005	1.00	0.454
134	10	0.0003	70	0.0004	0.73	0.693
234	10	0.0008	70	0.0009	0.88	0.555
1234	10	0.0003	70	0.0004	0.68	0.736

HEART RATE

1=EXERCISE 2=MODE 3=INTENSITY 4=REPETITIONS

Source of Variation	df Effect	MS Effect	df Error	MS Error	F Ratio	p value
1	1	7928.5	7	171.5	46.23	0.000
2	1	187.4	7	144.1	1.30	0.292
3	1	4580.6	7	207.4	22.09	0.002
4	10	2081.0	70	32.1	64.83	0.000
12	1	190.0	7	101.9	1.86	0.214
13	1	14.6	7	98.0	0.15	0.711
23	1	20.8	7	86.3	0.24	0.639
14	10	202.7	70	17.8	11.40	0.000
24	10	35.8	70	13.3	2.69	0.008
34	10	54.1	70	7.1	7.66	0.000
123	1	28.8	7	92.7	0.31	0.595
124	10	6.6	70	7.0	0.93	0.511
134	10	4.4	70	6.0	0.74	0.682
234	10	22.3	70	15.7	1.42	0.190
1234	10	4.0	70	10.9	0.37	0.955